SRDS Report No. RD-65-120

FINAL REPORT

Contract No. FA-65-WA-1192

Project No. 150-535-02A

SUMMARY OF SHORT-PERIOD TERMINAL WEATHER INFORMATION STUDIES

July 1964 through September 1965

October 1965

This report ... availability

Prepared for

FEDERAL AVIATION AGENCY

Systems Research & Development Service

By

THE TRAVELERS RESEARCH CENTER, INC.

250 Constitution Plaza Hartford, Connecticut 06103

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Prepared by

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ABSTRACT

Computer programs for converting data from punched paper tape to magnetic tape. and for decoding, error-checking, and summarizing the digital weather observations of the Federal Aviation Agency Mesonetwork surrounding Atlantic City, N.J. were developed and tested. The objectives and scope of these programs are described and sample outputs are illustrated. Twenty-five summer-season data samples from 5 to 8 mesonetwork stations were processed.

The total duration of low cloud and fog was smallest at a shoreline station (10) and greatest inland (at station 3). Among inland stations the least low cloud and fog occurred at NAFEC (station 1). Observations of low-cloud height were less representative in space than observations of visual range. Most of the onsets and endings of low cloud and fog for which data were available were due to formation and dissipation rather than to movement. Radiative cooling and heating appeared to be the predominant physical processes responsible for the onset and ending of low visibility conditions at inland stations. These results appear to be characteristic of the summer season in the Atlantic City area. To the extent that they can be compared, they are at variance with previous results based on late fall, winter, and spring data.

Simultaneous 4-min mean dew-point spreads and 4-min modal cloud heights in periods of continuous low cloud showed little or no correlation. However, when the data were smoothed by 20-min running averages the largest and most persistent changes in cloud height were accompanied by similar changes in dew-point spread. Evidence of a drop in temperature and a rise in dew point suggestive of evaporation was found just prior to and during the onset of precipitation at the surface. The measured wind speeds at several mesonetwork stations were found to be sensitive to local exposure conditions.

Brief summaries are given of the results of additional investigations carried out under the present project and previously described in other reports. These investigations were studies of space and time variations in transmission along runways at John F. Kennedy International Airport, case studies of fog and low cloud in the Washington, D. C. Mesonetwork, and studies of radar forecasts of visual range in snow.

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I. INTRODUCTION

Two of the most urgent requirements of aviation meteorology are recognized to be the need for improved information about terminal weather conditions and the need for accurate and timely short-period predictions of terminal weather conditions. These needs have arisen primarily out of a more general requirement for improvements in airport utilization, terminal area airspace utilization, and safety factors that depend on weather and many other variables. Despite remarkable improvements in airfield lighting, guidance systems, and traffic control procedures in recent years, airports continue to be closed at times due to weather; and delays, directly or indirectly attributable to weather, occur even with above-minimum conditions.

It is generally agreed that significant improvements in the specification and short-period prediction of terminal weather conditions are possible only if more, frequently cycled observations from a finer grid than that of the standard surface synoptic network are available. The first steps in this direction were taken with the development of continuously-recording ceilometers and visual range instruments, and with the installation of multiple transmissometers along major airport runways. More recently, special mesonetworks of weather observation stations were established around Washington National Airport providing continuous analog records, and around the National Aviation Facilities Experimental Center (NAFEC) of the Federal Aviation Agency at Atlantic City, New Jersey, providing high frequency digital data on paper tape. With data from these facilities, studies of small-scale space and time changes in weather parameters of concern to aviation terminal operations became possible.

Studies of runway observations have revealed worthwhile potential predictability of transmission or visual range in fog by kinematic methods for time periods of about 5 to 25 minutes [2,3]. A limited sample of data collected from the Atlantic City Mesonetwork in the first few months of 1963 permitted an extension of these studies to longer time periods and to visual range fluctuations in fast-moving snowstorms and rainshowers [4,5]. From this work it became clear that kinematic prediction techniques were of little use for shallow fog (restricted visual range at transmissometer height but no vertical obscuration), for small-scale showers of short lifetime, and for non-frontal fog formation and dissipation in very light winds. An evaluation of the usefulness of the mesonetwork was not possible at this time, however, as only a few stations were activated and many key variables were not measured.

This work was continued in late 1964 and early 1965 utilizing data collections from the U.S. Weather Bureau Mesonetwork around Washington National Airport. The main results are summarized in the present report, but for details the reader is referred to separate publications [6,8]. Meanwhile, following major modifications and improvements (after a shutdown from July, 1963 to June, 1964), individual stations of the Atlantic City Mesonetwork have been activated in the past year with the objective of full operation by late 1965. A total of 13 surface stations plus supplementary data sources were planned. The station locations (numbered from 1 to 13) are shown in Fig. I-1. Three conventional airways observation stations — Millville * (MIV, No. 13), Atlantic City (ACY, No. 14), and Philadelphia (PHL, No. 15) — are included in the figure.

* Millville and Mesonetwork Station 13 are shown at the same location in Fig. I-1.

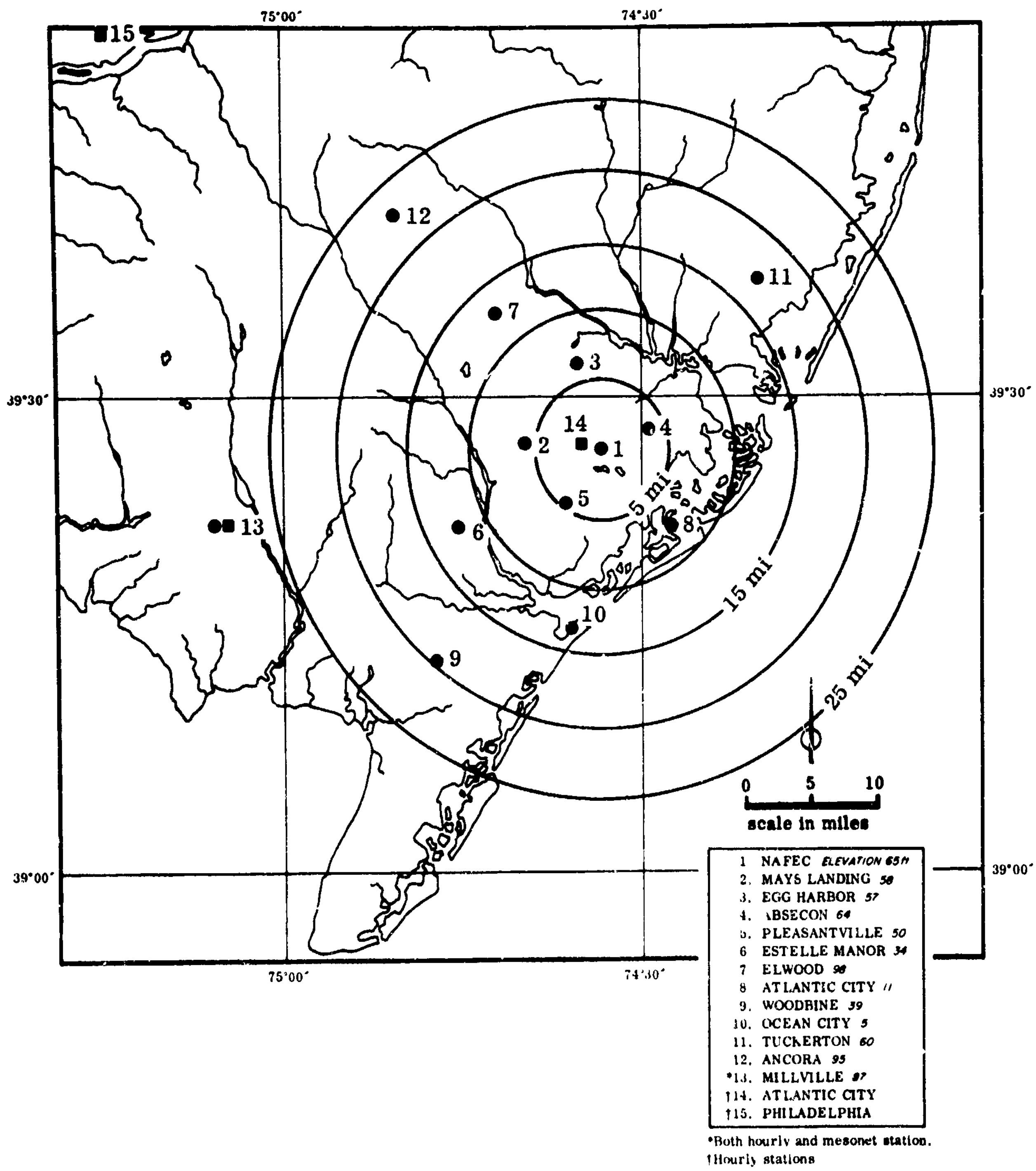

Fig. I-1. Atlantic City Mesonetwork station configuration.

The Travelers Research Center, Inc. has participated in this effort through the development and testing of computer programs for the initial processing of digital data from the mesonetwork and through the analysis of observations from 5 to 8 inner network stations collected in May, June, July, and August during a period of activation and shakedown. This work is described briefly in Appendixes A and B. Specifications, flow charts, program descriptions, operating instructions, and listings for the data processing computer programs are given in a separate document [1] . Due to time limitations, the scope of the analysis was limited to some investigations of the information content in measurements of individual variables and to interpretations of the onset and ending of periods of very low cloud and visual range.

II. SUMMARY

A. Studies of Runway Transmissometer Observations from John F. Kenned rnational Airport, New York.

Forty samples of data in fog and precipitation from three runway transmissometers at John F. Kennedy International Airport in the months from October, 1963 to June, 1964 were used to study the movement of the transmission field across the airfield. The time and space representativeness of these data was compared with that found previously for Atlantic City, N.J. These investigations were described in a report issued under Contract FA65WA-1192 [3] . The principal results are:

(a) A significant fraction of the variance of local time changes in transmission was accounted for by advection (fog without rain), warm front movement (fog with rain), and by advection of precipitation cells aloft (rain and snow showers).

(b) There was some evidence to suggest that the transmission field was less representative in space and time at Atlantic City than at John F. Kennedy Airport, particularly in fog that formed under clear skies at night. However, on the whole, the variability characteristics of transmission at the two terminals were remarkably similar.

B. Analyses of Fog and Low Clouds in the Washington, D.C. Mesonetwork Area

The detailed results of analyses of five data collections obtained during periods of low cloud and fog in three winter months in the Washington, D.C. Mesonetwork area were described in a report issued in June, 1965 under the present project [6] . The main findings from that study are:

(a) Low ceilings, visibilities, transmission in fog, and surface winds associated with low cloud and fog were essentially uncorrelated with simultaneous observations of the same parameters at distances of 50 miles or more.

(b) Minimum station spacings required for an average space autocorrelation coefficient of 0.7 between simultaneous observations of the parameters listed in (a) were found to be 4 miles for transmission (5-minute means), 5 miles for visibility (15-minute means), 15 miles for surface wind (5-minute means), and 25 miles for ceilings (15-minute means).

(c) The Washington, D.C. surface wind network data were of great value in identifying and following the motion of disturbances of the low-level air flow. Estimates of divergences of the air flow derived from these data appeared to be realistic.

(d) Most of the air flow disturbances that were associated with significant changes in ceiling and visibility moved quite regularly across the network and possessed lifetimes in excess of the short-period prediction times of greatest concern.

(e) Nocturnal cooling and evaporation of precipitation often appeared to be responsible for establishing high humidity conditions prior to fog and low-cloud formation. However, upward air motions at low levels appeared to be necessary also for condensation on the occasions studied.

(f) Evidence of quasi-conservative movement of transmission patterns in fog was obtained for time periods of up to 40 minutes in the few occurrences that could be studied with data from relatively closely-spaced transmissometers.

(g) Evidence of important effects on the behavior of low ceilings and visibilities due to terrain irregularities and vertical wind shear was presented.

C. Radar Forecasting of Visibility Restrictions in Snow

Quantitative radar echo-intensity data from two snowstorms were compared with visual-range data from seven transmissometers in the vicinity of the WSR-57 radar at Washington, D.C. Based on the percent reduction of variance, root-mean-square error, and percent hits error criteria, the radar-derived visual range forecasts were generally superior to persistence forecasts for time periods of 10 to 70 minutes. A logarithmic relationship was found between average radar-received power and visual range. The correlation between these two quantities was found to be highest for surface stations within 40 miles of the radar during periods of large variability. An improved forecast procedure in which the radar-derived predicted change in visual range is added to the observed initial visual range was recommended for testing in order to reduce the tendency of forecasts based on radar data alone to overshoot the observed visual range.

D. Development of Data Processing Computer Programs for Atlantic City Mesonetwork Observations

The following data processing computer programs were coded and checked out using mesonetwork data samples:

(a) Paper tape-to-magnetic tape conversion and preliminary error check,

(b) Input-Data-Handling (IDH Phase I) — final error check, data cleanup, and preliminary decoding,

(c) Input-Data-Handling (IDH Phase II) — final decoding, data reduction, and preparation of time series and map formats,

(d) Time-Series Translation program — selection of predictor stations, preparation of forecasts by extrapolation in space and time for three time periods, verification and error summary.

A general description of the objectives and means by which these objectives were accomplished, together with illustrations of the output of each program, is given in Appendix A. Complete specifications, program descriptions, and operating instructions are documented in a separate report [1]. Programs (a), (b), and (c) above were used to process 25 data collections recorded between 20 May and 20 August, 1965. Failures of programs (b) and (c) on two additional data collections were tentatively attributed to magnetic tape imperfections.

The performance of programs (a), (b), and (c) was judged to be satisfactory for routine use in the preparation of mesonetwork data for analysis with the exception of the cloud-height reduction routines in IDH Phase II. A modification to these routines is needed to improve discrimination between cloud layers.

Although the Time-Series Translation program performed satisfactorily in limited tests it appears likely that modifications will be needed in the future to increase its scope. In particular, in view of the results of analyses of the mesonetwork surface wind data, the use of a movement vector based solely on station 1 wind observations must be reexamined.

III. ANALYSES OF ATLANTIC CITY MESONETWORK DATA

The Government collected a total of 27 data samples consisting of simultaneous observations from 5 to 8 Mesonetwork stations at NAFEC from 20 May to 20 August, 1965. In this period they gradually brought newly-activated stations to an acceptable performance level with their emphasis, generally, on operational shakedown and testing of system components. Nevertheless, limited analyses of these somewhat fragmentary data yielded information that should be useful for interpreting the observations, for using the data processing programs, and for understanding local time changes in low cloud height and visual range. It is important to note that most of the data samples were collected in the summer season. The characteristics of these low-cloud and fog events, including their frequency and durations, were probably not representative of other seasons. Results of the analyses were:

(a) At Station 1 (NAFEC) totals were recorded of 4.9 hours (3 occurrences) with cloud-base height ≤ 200 ft and 13.1 hours (7 occurrences) with visual range ≤ 1/2 mi. The latter total represented less than one percent of all hours in the three months studied. A few occurrences were not sampled, but such low frequencies and brief durations of low cloud and fog are characteristic of the summer season at NAFEC.

(b) Comparisons of observations within the inner group of mesonetwork stations (Stations 1, 2, 3, 4, and 5) with each other, as a group with Station 10, and individually with Station 10 showed that the occurrences and durations were markedly less uniform in space for low cloud (≤ 200 ft) than for low visual range (≤ 1/2 mi). Using sampling periods for which data were available from all stations — no case was found in which low cloud (≤ 200 ft) was observed at each of Stations 1—5. However, in 4 out of 6 samples for which data were available from all stations low visual range (≤ 1/2 mi) was observed at each of Stations 1—5. Total durations of low cloud varied from 1.2 hours at Station 5, to 9.5 hours at Station 2. The total durations of low visual range varied from 2.5 hours at Station 10, to 13.7 hours at Station 5 (excluding Station 4, due to an inoperative transmissometer). For the condition cloud-base height ≤ 200 ft and/or visual range ≤ 1/2 mi, the smallest total durations occurred at Station 10 and, among inland stations, at Station 1.

(c) The large differences in low-cloud and fog conditions between Station 10 (near the ocean) and inland stations were attributed primarily to the absence of fog at Station 10 under conditions favorable for radiation fog at inland stations, and to the rapid dissipation of fog or very low cloud advected from ocean to land.

(d) Of three low-cloud or fog onset periods for which data were available, two appeared to be due primarily to radiative cooling and exhibited the extreme variability characteristic of shallow fog, while the third was due to advection. Of seven endings of low cloud and fog, six appeared to result from radiative heating and one from a combination of advection and possibly increased vertical mixing.

(e) The wind speeds at Stations 1—5 were found to be appreciably lower than those observed simultaneously at unobstructed anemometers at ACY, MIV, and Station 10. Furthermore, the magnitude of the difference in mean speeds varied with wind direction in rough agreement with the proximity of forest to the anemometers.

These results are interpreted as indications that micro-scale influences such as the size of the station clearing, distance from anemometer to forest, etc. are important factors in determining the observed wind speed. However, since analyses of the mesonetwork data in space can only be carried out for scales of the order of the station spacing or larger (i.e., greater than about 5 miles), wind observations that are dominated by smaller-scale effects will be of little use unless they can be corrected for these effects.

(f) Observed changes between consecutive 4-min mean dew-point spreads showed little or no relation to simultaneous changes in modal cloud height during period of continuous low cloud. However, when these data were smoothed by 20-min running averages the largest and most persistent changes in dew-point spread were found to be accompanied by changes of about the same sign and duration in cloud height. The onset of precipitation at the surface, as indicated by the rain detector data, was accompanied by a drop in temperature and a rise in dew point. Additional studies of this type involving the simultaneous behavior of two or more different parameters are needed to differentiate between noise, whether this is the result of errors or if real high-frequency fluctuations that cannot be analyzed, and information in the raw or processed data.

(g) Comparisons of original ceilometer observations with derived modal and low 10-percentile cloud-base heights showed that the derived values usually provided a reasonable summary of the data, but that a modification to the IDH programs is needed to avoid loss of information on multiple cloud layers.

IV. CONCLUSIONS

The principal conclusions from the investigation described in the appendixes, in this report, and in previous reports issued under Contract FA65WA-1192, are:

(a) The results of studies of time and space variations in atmospheric transmission at John F. Kennedy International Airport and in the Washington D.C. mesonetwork area fully support previous findings for NAFEC that a significant fraction of the most important 5- to 25-minute local changes in visual range can be explained by quasi-conservative movement of the transmission patterns in space. This result was based primarily on fall, winter, and spring observations from stations within relatively homogeneous terrains, and was not supported by summer season observations from the Atlantic City Mesonetwork.

(b) Minimum observation-station spacings required for meaningful analyses or descriptions of the fields of ceiling, visibility, transmission, and surface wind in the Washington, D.C. Mesonetwork area were found to be appreciably smaller than typical spacings found in the conventional surface synoptic network.

(c) The performance of individual stations in the Atlantic City Mesonetwork and the quality of the data collected in the period 20 May to 20 August, 1965 were vastly superior to station performance and data quality in the early months of 1963.

(d) It is concluded from tests with Atlantic City Mesonetwork data that all data processing computer programs developed for initial handling of the punched paper tape output of the network performed in an acceptable manner. The process of analysis was greatly accelerated by the automatic digital recording system of the network and by the use of data processing computer programs. Modifications suggested by these tests, such as a change in the cloud height reduction routines to improve the capability for multiple cloud layer discrimination in IDH Phase II, and changes to add flexibility to the time series translation program by correcting wind averages from Station 1, or by including wind vector information from additional stations, will enhance the usefulness of these programs.

(e) On the basis of studies of a few samples of radar reflectivity and transmissometer data, it is concluded that useful short-period predictions of visual range, or the trend in visual range in snow, at the surface can be made from radar-scope data. The prediction techniques can be adapted for manual or computer use.

(f) Although the Washington, D.C. Mesonetwork observations permitted detailed analyses of local changes in ceiling and visibility that would have been totally impossible with conventional data, a proper evaluation of the usefulness of this mesonetwork information for short-period terminal weather prediction could not be made in this study due to excessive station spacing in complex terrain, lack of frequent quantitative cloud height measurements, and excessive requirements for manual data processing of the analog records.

V. RECOMMENDATIONS

The following recommendations are based on a general review and assessment of all work carried out under Contract FA-65-WA-1192.

(a) The Atlantic City Mesonetwork, with automatic high-frequency digital recording of several variables including transmission, cloud-base height, and wind, with station spacings of 4—6 mi in the central area, with provisions for routine computer processing of data, and with evidence of a capability for producing relatively noise-free data, has now met the objections that have prevented a proper evaluation of the usefulness of such a network for terminal weather specification and short-period prediction. It is recommended that a program of kinematic technique development, testing, and evaluation, based on network and supplemental upper-air data (including radar data) from all seasons of the year be undertaken with the Atlantic City Mesonetwork. Furthermore, because of substantial progress in the development of numerical boundary-layer models in the past 2 to 3 years, it is recommended that present formulations of such models be used to assess the relative importance of various physical processes in fog and low-cloud formation and dissipation for the purpose of modifying and improving the kinematic prediction models.

(b) It is now possible, with data from the Atlantic City Mesonetwork, to carry out comprehensive studies of the spatial representativeness of observations of cloud-base height, transmission, and wind, to study the problem of optimum data sampling times for the purposes of specification and prediction, and to study the lifetimes and other variability properties of vortices, wind-shift lines, low-pressure troughs, and other disturbances associated with changes in low-cloud and fog conditions. It is recommended that such studies be initiated as soon as possible to provide a basis for optimizing the products of the mesonetwork, for improving the efficiency of data processing, and for recommending necessary changes in network design.

(c) The value of closely spaced wind observations as a supplement to the present surface airways weather data for preparing streamline analyses and divergence computations (as short-period forecast aids at terminals for which complete mesonetworks are not feasible) should be explored.

(d) Studies of the role of vertical motion in the formation and dissipation of low cloud and fog over relatively level terrain should be accompanied or followed by similar studies over inclined-plane-type terrain where dynamically-induced and orographic vertical velocities can be evaluated over comparable space scales. A mesonetwork equipped in much the same way as the Atlantic City Mesonetwork with a central station and a square array of 4 stations at distances of about 10 miles from the center and 4 supplementary surface wind stations should be adequate for these studies. Terrain requirements could be satisfied by an area with a slope of about 50 ft per mile in the Great Plains region.

(e) In order to adapt kinematic short-period prediction models to terrain similar to that in the Washington, D.C. area, modifications are needed to account for differences in station elevation and for reductions in air speed in confined valleys or basins. It is recommended that existing information on wind variations in complex

terrain be synthesized for application to this problem and that the possibility of relating visual-range observations to cloud-height measurements be explored as a method of specifying visual range at stations of various altitudes under a low-cloud blanket.

(f) It is recommended that further tests be made with a larger data sample to determine the operational usefulness of radar in short-period forecasting of visual range in snow and heavy rain.

(g) Because the data processing computer programs developed for Atlantic City Mesonetwork data are experimental in nature and can be significantly improved as more information on the characteristics of the data and the processing requirements is obtained, it is recommended that the program modifications needed to achieve these improvements be carried out.

(h) Although information on microscale or local-station environment winds is likely to be useful for example, as an indicator of possible radiation fog under suitable conditions, the most urgent requirement is for mesoscale wind data from the network. It is recommended that the feasibility of deriving mesoscale data by suitable adjustments of the observations in wind speed and direction classes at individual stations be investigated.

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5. _________, _________, and _________, 1963: Further Studies of Atmospheric Transmission Data from the Federal Aviation Agency Atlantic City Mesonetwork, Tech. Note prepared under U.S. Weather Bureau Contract Cwb-10704, The Travelers Research Center, Inc.

6 _________, and _________, 1965: Case Studies of Fog and Low Clouds in the Washington, D.C. Mesonetwork Area, Final Report 7468-166 Contract FA65WA-1192, The Travelers Research Center, Inc.

7. Second International Aviation R&D Symposium, Sept. 16-18, 1963: "All-Weather Landing Systems," Summary of Discussions and Program Progress Report, Office of International Aviation Affairs, Systems Research and Development Service, Federal Aviation Agency (Fig. 38, p. 125).

8. Wilson, J.W., 1965: Radar Forecasting of Visibility Restrictions in Snow, Tech. Rpt. 7468-172, Contract FA65WA-1192, The Travelers Research Center, Inc.

APPENDIX A. MESONETWORK DATA PROCESSING COMPUTER PROGRAMS

I. INTRODUCTION

At Mesonetwork Data Central, coded weather messages are received simultaneously from each station and punched sequentially on 5-channel paper tape by individual BRPE punch machines. Several computer programs that will accept these data on punched paper tapes, and will accomplish routine input-data-handling (IDH) tasks prior to analysis, were prepared to facilitate the processing of large quantities of data. In addition, one computer program was prepared for short-period predictions, by horizontal movement or translation, of cloud-base height and transmission. Brief descriptions of the objectives and structure of these programs, together with sample inputs and outputs, are presented here. Complete details, in the form of specifications, program descriptions, operating instructions, and listings, are given in a separate document [1].

A simplified chart showing the flow of data from observation stations through each processing program, to the various forms of output available at the present time, is shown in Fig. A-1. Various intermediate working tapes and input/output control functions are not shown to avoid unnecessary complication of the overall structure.

Running time Estimates for

ACY Mesonet Computer Programs

Program Name	Running Time
DDP-24 tape to tape conversion	.50 min/hr/station
IDH-Phase I	.25 min/hr/station
IDH-Phase II	.38 min/hr/station
Time series translation prediction program	1.00 min/run

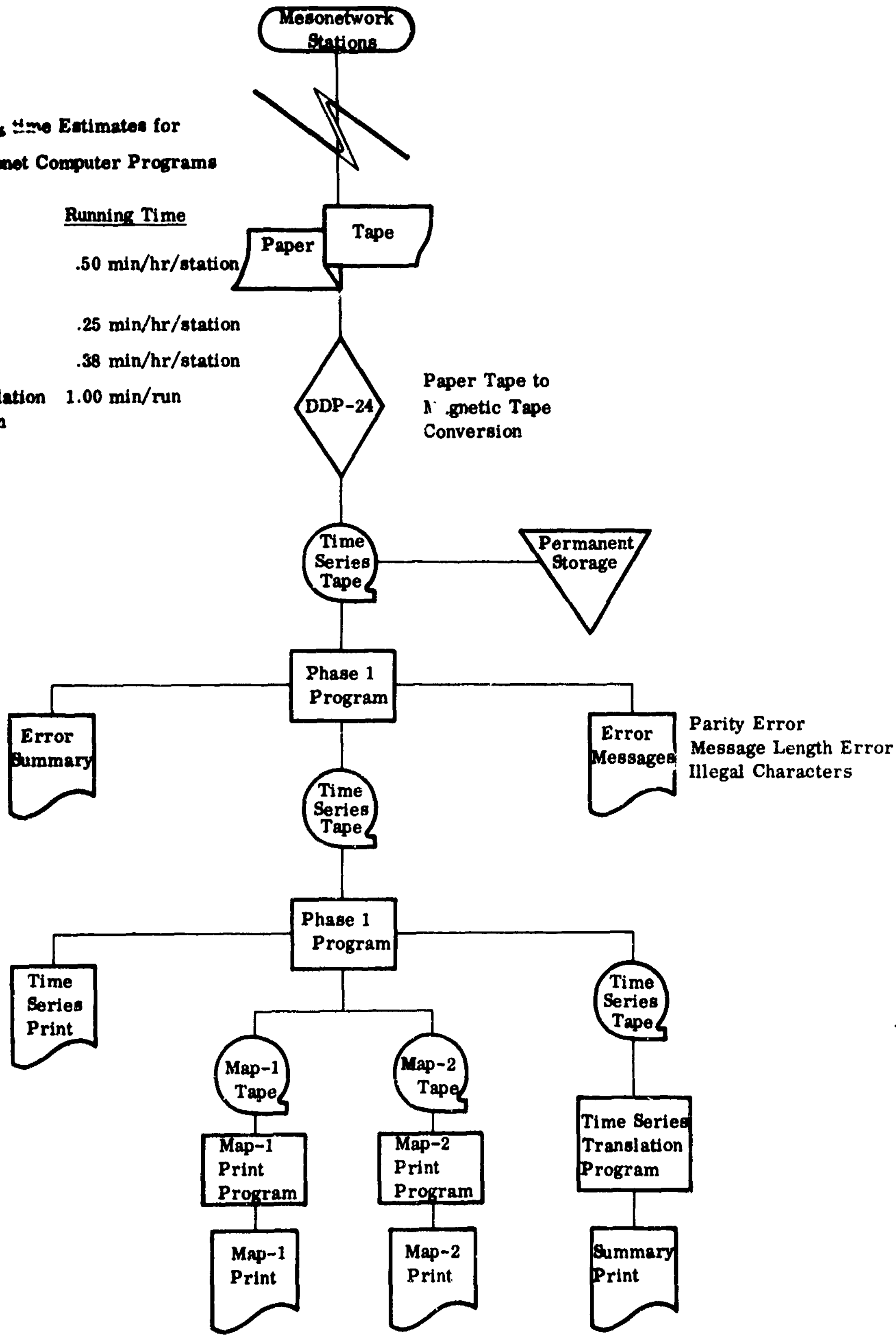


Fig. A-1 Flow chart showing initial computer processing of mesonetwork data.

II. PAPER TAPE TO MAGNETIC TAPE CONVERSION PROGRAM

The mesonetwork weather message format is shown in Table A-1. The time between observations is 12 seconds for cloud-base height and 24 seconds for all other parameters. Free channels are used at some stations for soil temperatures at specified levels. The format requires no alphabetic characters. A coding chart is shown in Fig. A-2.

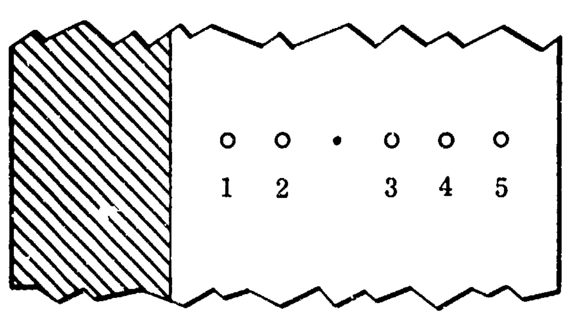
TABLE A-1
MESONETWORK WEATHER MESSAGE FORMAT

Item	Number of characters	Allowed range	Basic decimal unit
Figures code	1	NIL	____
Station identifier	2	01 to 13	____
Day	3	001 to 365	1.0 day
Hour	2	00 to 23	1.0 hr
Minute	2	00 to 59	1.0 min
Sub-format indicator	1	1 or 3	____
Space	1	NIL	____
Temperature	3	080 to 650	0.1° C
Dew-point temperature	3	300 to 999	0.1° C
Free channel	3	000 to 999	____
Free channel	3	000 to 999	____
Space	1	NIL	____
Free channel	3	000 to 999	____
Free channel	3	000 to 999	____
Pressure	3	200 to 850	0.1 mb
Transmission	2	00 to 98	1.0 %
East-west wind component	3	* -40 to +40	1.0 knot
North-south wind component	3	-40 to +40	1.0 knot
Space	1	NIL	____
Rain count	1	0 to 5	0.01 in./24 sec
Rain-no rain indicator	1	1 or 2	____
Tangent of elevation angle 1	3	# 000 to 600, or 999	0.1
Tangent of elevation angle 2	3	000 to 600, or 999	0.1
Tangent of elevation angle 1	3	000 to 600, or 999	0.1
Tangent of elevation angle 2	3	000 to 600, or 999	0.1
Carriage return	1	NIL	____
Line feed	1	NIL	____

*The system capability will allow these limits to be adjusted to values as high as ±98.

#The rotating beam ceilometer system is calibrated accurately for values up to 0.37. Above this the measurements become less accurate as the angle increases. The value 999 is a no cloud indicator.

Character	Punch number perforated				
1	1	2	3		5
2	1	2			5
3	1				
4		2		4	
5					5
6	1		3		5
7	1	2	3		
8		2	3		
9				4	5
0		2	3		5
Line Feed		2			
Carriage return				4	
Space			3		
—Sign	1	2		4	5
Figures	1	2		4	5
?	1			4	5



o Channel punched hole

• Feed sprocket holes

BRPE punch arrangement

Fig. A-2. Mesonet punch arrangement and character code.

All weather messages are converted from 5 channel teletype code on punched paper tape to digital code on IBM magnetic tape (BCD mode, 556 bits/in.) by means of a DDP-24 computer. During this process, messages of incorrect length or messages containing illegal characters are flagged on tape by the figure 1 at the end of each message. Illegal characters are replaced by alphabetic letters that can be identified from hard copy output. A sample of hard copy from the magnetic tape output is shown in Fig. A-3. A list of erroneous messages from Stations 1 and 2 for the period 1401–2153 EST, 27 May 1965, is shown in Fig. A-4.

```
LS02147140013C556906750750C74975055590-C3-C9CC1999999999999981
S02147140013C55490675175OC75C7505559CCC4-11CC1999999999999BGC
SC2147140023C55490675175OC75C7505559C-C1-14CC1999999999999BGC
S02147140023C5559057517500C75C7505549C-C4-12CC1999999999999BGC
S02147140033C5539057507500C75075155490CC1-10CC10CCC59999999BGC
S02147140033C556904751750C75075055490CC1-10CC1999999999999BGC
S02147140033C558905750750C75075055490-C2-06CC1999999999999BGC
S02147140043C558906751751C75075055590-C4-1CCC100CC0599999BGC
S02147140043C559906751751C75175055590-C3-C9CC1999999999999BGC
S02147140053C557906751750C74975055490-CC-11CC1999999CCCCC5BGC
S02147140053C557904751751C75175055491-C3-1CCC1999999999999BGC
S02147140053C557903751750C75075055490-C1-11CC1999999999999BGC
S02147140063C556902751750C75175055490-C5-13CC1999999999999BGC
S02147140063C556901751750C75075055490-C2-13CC1999999999999BGC
S02147140073C556900751750C75075055390-C2-12CC1999999999999BGC
S02147140073C555900751751C75075055390-C2-C9CC1999999999999BGC
S02147140073C554899751751C75175155490-C3-C9CC1999999999999BGC
S02147140083C556899751751C75175155491-C3-C9CC1999999999999BGC
S02147140083C557900751750C74975055391-C2-C8CC1999999999999BGC
S02147140093C556900751751C751750553CCCC-06CC1999999999999BGC
S02147140093C557901751751C75075055391CC6-C9CC1999999999999BGC
S02147140093C556901751751C75075055391CC5-C5CC199999CC9999BGC
S02147141003C556900751751C75175055291CC2-1CCC1C03999999999BGC
S02147141003C556900751751C75075055391CC6-1CCC1999999999999BGC
S02147141013C556900751751C75175155391CC7-11CC1999999999999B1
S02147141013C557900751750C75075055391CC1-16CC1999999999999BGC
S02147141013C558901751751C75075055390CC2-12CC1999999999999BGC
S02147141023C558901751751C75175055290-CC-1CCC1999999999999BGC
S02147141023C560902751751C75075055290-C2-09CC1999999999999BGC
S02147141033C560903751750C75075055290CC1-C8CC1999999999999BGC
S02147141033C559903751750C75075155290CC0-07CC1999999999999BGC
S02147141033C559903751750C75075055291-C4-06CC199999CCCCC4BGC
S02147141043C560903751751C75075055190-CC-07CC1999999999999BGC
S02147141043C560904751750C75075155190-C1-11CC1C0CCC5999999BGC
S02147141053C557903751751C75075055290-C1-06CC1999999999999BGC
S02147141053C559901751750C75075055291CC2-C9CC1999999999999BGC
S02147141053C560902751751C75175055291-C1-C8CC1999999999999BGC
S02147141063C560904751751C75075055290-C1-1CCC1999999999999BGC
S02147141063C559903751751C75175055190CC1-14CC1999999999999BGC
S02147141073C559902751751C75175055290CCC-1CCC1999999999999BGC
S02147141073C559901751750C75075055C91CC5-10CC199999CC5999BGC
S02147141073C559900751750C75075055191CC3-13CC1999999999999BGC
S02147141083C557900751751C75175155191CC3-13CC1999999999999BGC
S02147141083C560900751751C75075055190-CC-C9CC1999999999999BGC
S02147141093C559900751751C75075055190-C1-C9CC1999999999999BGC
S02147141093C559900751751C75175155190CCC2-C8CC1CCCCC599999BGC
S02147141093C560900751751C75175055190-C1-09CC1CCCCC599999BGC
S02147141203C559901751751C75175055C90CCC-C8CC199999C1C999BGC
S02147141203C560901751750C75075055C90-CC-11CC1999999999999BGC
S02147141213C560902751751C75175055190CC4-1CCC1C0CCC599999BGC
S02147141213C561902751751C75075055C90CC1-07CC1999999999999BGC
S02147141213C564902751751C75175054990CC1-13CC1999999999999BGC
S02147141223C561903751750C75075054991CC1-12CC1CCCCC599999BGC
S02147141223C561902751750C75075154990CCC-07CC199999CCCCC5BGC
S02147141233C561902751751C75075155090CC2-12CC1999999999999BGC
S02147141233C561902751751C75175154990CC9-C9CC1999999999999BGC
S02147141233C560902751750C75075055090-CC-11CC1999999999999BGC
S02147141243C560902751751C75075054990CC1-12CC1CCCC4999999BGC
S02147141243C560902751750C75075054990CCC-13C11999999999999BGC
S02147141253C558902751750C75175055090-C2-11CC1999999999999BGC
```

Fig. A-3. Listing of sequential mesonetwork weather messages from station 2 following conversion from paper tape and preliminary error checking in the DDP-24 computer.

```
BAD MESSAGE S0114720093C4538677749749C74974956693C03-00C02999999G0000001
BAD MESSAGE 014999BG000000000000000000000000000000000000000000000000001
BAD MESSAGE S0114720183C4538697749749C74974956493C01C00C02999999999BG001
BAD MESSAGE SC114721053C4548707749749C74974955699 4C01-01C01999999999999B1
BAD MESSAGE S0114721123C4548727749748C74974957093C01-00C01999999999999B1
BAD MESSAGE S01147211333C4548717487 48C74974957193C00-00C01999999999999B1
BAD MESSAGE S0114721263C4538870749749C74874957295C00-00C02999999999999B1
BAD MESSAGE S0114721303C4538697487 49C74974955739 5C00-00C01999999999999B1
BAD MESSAGE SC114721533C4518647487 49C74874958294C01-05C01999999999999B1
BAD MESSAGE LS02147140 13C556906750750C74975055590-03-09C01999999999999B1
BAD MESSAGE S0214714113C556900751751C75175155391C07-11C01999999999999B1
BAD MESSAGE S0214715083C559990575175 0C75075154691C01-05C01999999999999B1
BAD MESSAGE SC214715153C55790475177 50C75175054690C02-08C0100000300399 9B1
BAD MESSAGE S0214715173C560990475175 1C75175054590C01-07C01999999999999B1
BAD MESSAGE S0214716033C556902751751C75075055390CC04-08C0100199999999 9B1
BAD MESSAGE SS0214716313C539898751751C75175054990C03-06C0100000499999B1
BAD MESSAGE S0214717163C519891751750C75075154991C01--04C01999999999999B1
BAD MESSAGE S0214717283C5218737517 51C75075056288 9-09005C01999999999999B1
BAD MESSAGE S021717283C520868751751C75175056289-08C09C0100100399999 9BG01
BAD MESSAGE S0214717293C520864751C750C75075156289-07C06C01999999999999-1
BAD MESSAGE S0214717413C483859751751CC75175155383-02C05C12999999999999B1
BAD MESSAGE S0214718193463872751751C75175056292-00-03C0101399999999BG01
BAD MESSAGE S0214718313C467885875175 1C75175057098-03-05C020399990409 99B1
BAD MESSAGE S0214718523C451864751750C75075155890C02C01C0100000299995021 1
BAD MESSAGE 999999999999BG000000000000000000000000C00000C0000C000000001
BAD MESSAGE 0214718533C450864751751C75075155790C02C01C0100000299999BG01
BAD MESSAGE S0214718533C449864752751C750750557C02C01C010469990079 99BG001
BAD MESSAGE S0214718553C450867751751C75075055990C0C00C0100000299999BG01
BAD MESSAGE S0214719193C4538707517752C75175157488-00-04C01008999999999B1
BAD MESSAGE S0214719283C455867752751C751G0000000000000000000000000000C1
```

Fig. A-4. Listing of erroneous messages from stations 1 and 2 in the period 1401–2153 EST, 27 May, 1965 detected by the DDP-24 error-check program.

III. DECODING AND ERROR-CHECK PROGRAM (PHASE 1)

The purposes of this program are to identify the most obvious errors not previously flagged in the conversion program, to convert coded characters to forms more useful for analysis, and to structure the data in such a way that complete ordered sequences of messages are available for subsequent processing. As shown in Fig. A-1 the output of Phase I is given in three forms — a summary of all errors, a list of messages of incorrect length or containing parity errors or illegal characters, and a packed binary data tape to be used as input to subsequent data processing programs. The first two forms of output have been useful for daily maintenance checks of mesonetwork performance, as well as for providing a method for rapidly checking many aspects of data quality prior to analysis. The principal error-checks are described briefly in the following section.

A. Summary of Error-Check Criteria

A list of symbols and abbreviations is given in Table A-2. These are used in Table A-3 to provide a complete summary of the types of error checks, the criteria, and the error codes used in the IDH Phase I computer program.

TABLE A-2
SYMBOLS USED IN DESCRIBING ERROR CHECKS

Symbol	Definition
N	Total number of characters in one message
ID	Station number code
IPn	Input control value, n
t_i	Date-time code for i^{th} message
VO	Voltage code
F	Format code
T	Temperature code
TD	Dew-point temperature code
P	Pressure code
U	East-west wind component code
V	North-south wind component code
RC	Rain count (precipitation amount) code
RNR	Rain — no rain code
CH	Cloud-base height code
TR	Transmission code

TABLE A-3
SUMMARY OF MESONETWORK WEATHER MESSAGE ERROR CHECKS INCLUDED IN THE DDP-24 AND IDH PHASE I COMPUTER PROGRAMS

Type of Error	Criterion	Error Code or Action
Message Length	$N \neq 59$	INCORRECT NUMBER OF CHARACTERS
Illegal characters	All legal characters are shown in Fig. A-2	NON-ACCEPTABLE CHARACTER
Station number	$ID \neq IP1$	INCORRECT STATION ID
Date-time check	$t < IP2$	PROCEED TO IP2
	$t > IP2$	RESET IP2, WRITE MISSING MESSAGES
	$t_i - t_{i-1} < 0$	TIME DECREASE
	$t_i - t_{i-1} = 0$	NO CHANGE IN TIME
	$t_i - t_{i-1} > 1$ (min)	TIME INCREASE, WRITE MISSING MESSAGES
Voltage check	$\lvert VO - 750 \rvert > IP4$	VOLTAGE VAR
Extreme range	$F \neq 1,3$	NON-ALLOWED VALUE — FORMAT
	T < 080, T > 650	NON-ALLOWED VALUE — TEMPERATURE
	TD < 300, TD > 999	NON-ALLOWED VALUE — DEW-POINT
	P < 200, P > 850	NON-ALLOWED VALUE — PRESSURE
	TR < 00, Tr > 99	NON-ALLOWED VALUE — TRANSMISSION
	U < -40, U > +40	NON-ALLOWED VALUE — U-WIND COMPONENT
	V < -40, V > +40	NON-ALLOWED VALUE — V-WIND COMPONENT
	RC < 0, RC > 5	NON-ALLOWED VALUE — PRECIPITATION AMOUNT
	$RNR \neq 1,2$	NON-ALLOWED VALUE — PRECIPITATION INDICATOR

TABLE A-3 (Cont'd)

Type of Error	Criterion	Error Code or Action
Extreme range	CH < 000, CH > 600 except CH=999 allowed	NON-ALLOWED VALUE — CLOUD HEIGHT
Cross variation	T - TD < 0	TEMP LOW OR TD HIGH
	$(CH)_1 - (CH)_2 \geq 0$	CLD HT 2 - LOW
	$(CH)_3 - (CH)_4 \geq 0$	CLD HT 4 - LOW
	TR > IP5 when RNR=2	TRANS HIGH
	TR ≤ IP7 when T-TD ≥ IP6	TRANS LOW
	RC > 0 when RNR=1	NAG RNR RC
Maximum variation	$T_i - T_{i-1} > IP8$	TEMP VAR
	$TD_i - TD_{i-1} > IP9$	TD VAR
	$P_i - P_{i-1} > IP10$	PRESS VAR
	$TR_i - TR_{i-1} > IP11$	TRANS VAR
	$U_i - U_{i-1} > IP12$	WIND U VAR
	$V_i - V_{i-1} > IP12$	WIND V VAR
Minimum variation	$\sum_{i=1}^{i=IP13} T_i - T_{i-1} = 0$	NO TEMP VAR
	$\sum_{i=1}^{i=IP13} TD_i - TD_{i-1} = 0$	NO TD VAR
	$\sum_{i=1}^{i=IP14} (P_i - P_{i-1}) = 0$	NO PRESS VAR
	$\sum_{i=1}^{i=IP15} (TR_i - TR_{i-1}) = 0$	NO TRANS VAR
	$\sum_{i=1}^{i=IP16} (U_i - U_{i-1}) = 0$	NO WIND U VAR
	$\sum_{i=1}^{i=IP16} (V_i - V_{i-1}) = 0$	NO WIND V VAR

TABLE A-3 (Cont'd)

Type of Error	Criterion	Error Code or Action
Minimum variation (cont'd.)	$\sum_{i=1}^{i=IP18}(CH_i - CH_{i-1}) = 0$ when CH ≠ 999 (cloud groups 1 and 3)	NO LOW CLOUD HEIGHT VAR
	$\sum_{i=1}^{i=IP18}(CH_i - CH_{i-1}) = 0$ when CH ≠ 999 (cloud groups 2 and 4)	NO HIGH CLOUD HEIGHT VAR
	$\sum_{i=1}^{i=IP17}(CH1 - CH3)_i = 0$ when CH=999	NO CLOUD HEIGHT

B. Station and Time Error Checks

Punched cards are used to specify the number of stations to be processed, the order in which station data are to be processed, and the date and time of the first message. This information is then used to check the station identification numbers and to verify the occurrence of properly increasing date-time groups. Missing messages and messages with erroneous station or time groups are replaced by dummy coded messages in order to provide an unbroken sequence. If more than a specified number of consecutive occurrences of incorrect station identification, no time change, or decreasing time change are found, processing is discontinued for that data sample and transferred to the next station on the tape.

C. Reference Voltage Check

A reference voltage is normally coded in each free channel of each message. If the coded value is not within acceptable limits the occurrence is identified and the message is replaced.

D. Extreme Range Error Check

Each of the variables —format indicator, temperature, dew-point temperature, pressure, transmission, wind components, precipitation amount, precipitation indicator, and cloud-base height —is checked for the occurrence of numerical values within the appropriate ranges. Illegal numerical values are identified.

E. Cross Variation Error Checks

Five error criteria, involving two or more variables in the same message, are included in the program. For each violation the time and an error code are noted. The specific criteria and error codes are summarized in Section F.

F. Maximum and Minimum Variation Error Checks

Changes between consecutive values of the same variable are compared with specified allowed values for both maximum and minimum variations. These criteria were designed for the detection of excessive noise and of sensor or communication failure.

G. Output of Phase I

1. Times Series Data

As shown in Fig. A-1, a major product of the Phase I computer program is a time series (Station 1, all messages; Station 2, all messages; ....) magnetic tape. On this tape 38 words are used to record the data and the error identifiers in binary mode for each message. The data are in blocks of 100 messages (3800 words per record). The magnetic tape serves as input to IDH Phase II.

2. Error Summaries

A summary of gross errors and suspicious occurrences in the data, together with a list of messages containing such occurrences, is provided by the IDH Phase I computer program. Sample summaries for Station 2 for the period 1428—2159 EST, 27 May 1965, are shown in Fig. A-5(a). A list of individual occurrences for the same station and time period is given in Fig. A-5(b). The tolerances specified as limits for allowed cross variations or maximum variations between consecutive readings are tabulated at the bottom of Fig. A-5(a).

ERROR SUMMARY
STATION 2

PAGE 1

PARAMETER	NO. OF DISALLOWED VALUES	PERCENT OF TOTAL
STATION ID	0.	0.
DAY	0.	0.
HOUR	0.	0.
MINUTE	1.	0.09
SUB-FORMAT	0.	0.
VOLTAGE	0.	0.
TEMPERATURE	0.	0.
DEW-POINT TEMPERATURE	0.	0.
PRESSURE	0.	0.
U WIND COMPONENT	0.	0.
V WIND COMPONENT	0.	0.
PRECIPITATION AMOUNT	0.	0.
PRECIPITATION INDICATOR	0.	0.
CLOUD HEIGHT	0.	0.

Fig. A-5 (a). IDH Phase 1 error summary for station 2 for the period 1428—2159 EST, 27 May, 1965.

ERROR SUMMARY
STATION 2

PAGE 2

ERROR ID	NUMBER OF ERRORS	PERCENT OF TOTAL
TEMP LOW OR TD HIGH	0.	0.
CLD HT 2-LOW	1.	0.09
CLD HT 4-LOW	0.	0.
TRANS HIGH	0.	0.
TRANS LOW	0.	0.
MAG RNK RC	4.	0.35
TEMP VAR	0.	0.
TD VAR	0.	0.
PRESS VAR	0.	0.
TRANS VAR	1.	0.09
WIND U VAR	1.	0.09
WIND V VAR	0.	0.
NO TEMP VAR	0.	0.
NO TD VAR	0.	0.
NO PRESS VAR	0.	0.
NO TRANS VAR	1.	0.09
NO WIND U VAR	0.	0.
NO WIND V VAR	0.	0.
NO CLOUD HT	0.	0.
NO CLOUD HT VAR	0.	0.

NUMBER OF EXPECTED REPORTS = 1151.
NUMBER OF MISSING OR ERRONEOUS REPORTS = 30.
PERCENT MISSING OR ERRONEOUS = 2.61

INPUT PARAMETERS(IP)

	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
TOLERANCES	3.	94.	8.C	70.	1.5	1.5	10.0	10.	15.	80.	150.	80.	50.	100.	50.

Fig. A-5 (a) cont'd.

STATION 2

```
FIRST RECCRD                      214714213560902751751751750551 90  4-1001  0  5999999
NAG RNR RC                        21471424356090275175075075054990  0-1311999999999999
NO TRANS VAR                      21471600355590175175175075055390  1 -501999999999999
WIND U VAR                        21471730351986075175175075056289-20  501999999999999
NAG RNR RC                        21471844345786475175175175056691  0 -011  1 10 10999
TIME IN ERROR,LAST GOOD MESSAGE      21471929345586675175175175058987 -6 -202 10999  5  9
              MESSAGE IN ERROR       21471929345586675175075075059176 -8 -602  8999  0  1
TRANS VAR                         21471931345486575275175175258974 -4 -412  9999  7  9
CLD HT2 - LOW                     21471944345885975175075075057789 -0 -502  1  1  0  1
NAG RNR RC                        21472017345086875175175175157388  0 -011  0  1999999
NAG RNR RC                        21472038345187075175175175157489  0 -211999999999999
LAST RECCRD PROCESSED             21472200345587475175175075159190 -0 -401999999  0  1
```

Fig. A-5 (b). List of individual messages containing errors or suspicious occurrences at station 2 in the period 1423—2159 EST, 27 May, 1965.

IV. DATA REDUCTION AND FORMAT CONVERSION PROGRAMS (PHASE II)

The data sampling rate used in the Atlantic City mesonetwork (one message/24 seconds) was chosen partly for convenience and partly to provide data for the study of high frequency time changes in some variables. The present configuration will permit experimentation with different observation sample sizes and with various initial data processing techniques. Information on operational requirements, on the characteristics of prediction models, and on the characteristics of the instruments will provide the necessary guidance for such experimentation.

The Phase II computer programs were designed to convert the raw mesonetwork data to alternate forms, such as arithmetic means and measures of variability representative of time periods generally of the order of 2 to 20 minutes, and to convert the original time-series format (Station 1, all messages; Station 2, all messages) to either a new time-series format (Station 1, variable 1, all messages; Station 2, variable 1, all messages) or to synoptic-map format (variable 1, all stations; variable 2, all stations). Special tasks such as the conversion of data from pressure code to sea-level pressure and the conversion of ceilometer beam tangent values to cloud-base height are also accomplished in Phase II programs.

Consecutive equal non-overlapping data subsamples are used for the computation of average values of temperature, dew-point temperature, pressure, resultant wind speed and direction, east—west and north—south wind components, and transmission. Median cloud height values (for bases above 1000 feet) or modal cloud heights (for bases below 1000 ft) are computed from the subsamples. Running means are computed for precipitation amount. The selections of subsample size and output format are governed by input control cards.

Two maps are required to display simultaneous mesonetwork observations. Map 1 [see Fig. A-8(a)] displays temperature, dew-point temperature, pressure, rain count, and the rain—no rain indicator. Map 2 [Fig. A-8(b)] displays the resultant wind speed and direction, the speed and direction of the maximum wind in the subsample, the median or modal low-cloud height, median high-cloud height, the lowest 10 percentile of cloud height observations, and transmission. Map 2 [Fig. A-8(b)] also shows the occurrence and sign of the latest significant change of wind, transmission, and cloud height between map times. Criteria for the definitions of significant changes are specified by input control cards.

A. Output of Phase II

To illustrate the time series output of IDH Phase II, sequential 4-minute arithmetic mean values of temperature, dew-point temperature, sea-level pressure, wind speed, and wind direction are listed in Fig. A-6(a) for Station 1 for the period 0713—1045 EST, 3 June 1965. Following a complete array of these variables from a given data collection period, 4-minute mean values of transmission, u and v wind components, and median or modal cloud-base heights (not shown here) are listed for the same station. At the end of data sequences of this type for all stations precipitation data are presented as shown, for example, in Fig. A-6(b).

STATION 1 MEANS OF 4 MINUTE VALUES

DAY	HRMN	TEMP	TD	PRESS	SPD	DIR
154	713	13.6	12.4	1012.5	10.6	41.5
154	717	13.6	12.4	1012.5	11.6	41.1
154	721	13.6	12.5	1012.6	11.8	41.9
154	725	13.6	12.4	1012.7	10.9	52.6
154	729	13.5	12.4	1012.7	11.4	44.6
154	733	13.5	12.3	1012.6	13.5	43.5
154	737	13.5	12.3	1012.6	12.3	47.6
154	741	13.4	12.3	1012.6	12.9	42.2
154	745	13.4	12.3	1012.7	12.0	43.0
154	749	13.3	12.2	1012.9	11.9	37.2
154	753	13.2	11.8	1013.1	14.5	37.4
154	757	13.1	11.7	1013.2	14.3	34.9
154	8 1	13.0	11.7	1013.4	12.5	35.9
154	8 5	12.9	11.7	1013.3	10.6	40.8
154	8 9	12.9	11.8	1013.1	11.6	52.0
154	813	12.8	11.7	1013.1	10.4	51.9
154	817	12.9	11.9	1013.2	10.1	49.0
154	821	13.0	11.9	1013.3	9.4	51.1
154	825	13.0	12.0	1013.3	8.7	53.4
154	829	13.0	12.2	1013.4	8.4	47.4
154	833	13.0	12.2	1013.4	7.5	43.9
154	837	13.0	12.1	1013.3	9.8	4[illegible].5
154	841	13.1	12.1	1013.3	10.8	45.8
154	845	13.2	12.2	1013.3	10.8	35.6
154	849	13.2	12.2	1013.3	10.9	35.5
154	853	13.1	12.0	1013.4	13.1	25.3
154	857	13.1	12.0	1013.4	9.9	28.9
154	9 1	13.0	11.9	1013.4	11.5	31.5
154	9 5	12.9	11.6	1013.5	12.7	25.6
154	9 9	12.9	11.6	1013.6	13.0	32.1
154	913	12.8	11.6	1013.6	12.4	30.5
154	917	12.9	11.5	1013.6	11.5	31.9
154	921	12.9	11.6	1013.7	11.4	28.4
154	925	12.9	11.7	1013.7	9.9	36.8
154	929	12.9	11.[illegible]	1013.7	10.5	45.3
154	933	12.9	11.7	1013.7	12.3	4[illegible].4
154	937	13.0	11.8	1013.8	9.6	33.5
154	941	13.1	12.0	1013.8	9.6	41.2
154	945	13.0	12.0	1013.8	8.4	31.9
154	949	13.1	12.0	1013.9	6.5	25.5
154	953	13.2	12.0	1014.0	7.0	29.4
154	957	13.3	12.1	1014.0	7.9	2[illegible].8
154	10 1	13.3	12.0	1014.0	9.4	24.7
154	10 5	13.4	12.1	1013.9	7.5	26.9
154	10 9	13.6	12.3	1013.9	8.6	37.9
154	1013	13.8	12.4	1014.0	8.6	29.2
154	1017	13.9	12.3	1014.1	9.9	35.6
154	1021	13.9	11.7	1014.2	12.6	35.8
154	1025	14.0	11.4	1014.2	12.5	47.9
154	1029	13.9	11.2	1014.3	11.1	[illegible]
154	1033	13.9	10.9	1014.4	12.3	3[illegible].4
154	1037	13.8	10.9	1014.4	11.5	36.9
154	1041	13.9	10.8	1014.4	10.8	37.5
154	1045	13.9	10.8	1014.4	9.9	[illegible]

Fig. A-6 (a). Output of IDH Phase 2 in time series format showing 4-min mean values of temperature (TEMP), dewpoint temperature (TD), pressure (PRESS), wind speed (SPD), and wind direction (DIR) at station 1 for the period 0713—1045 EST, 3 June, 1965.

16 MINUTE TOTALS OF PRECIPITATION AMOUNT AT 8 MINUTE INTERVALS

DAY	HRMN	STATIONS 01	02	03	04	05	06	07	08	09	10	11	12	13
154	725	0.01	0.01	0.02	0.01	0.	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	733	0.02	0.02	0.02	0.02	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	741	0.03	0.03	0.02	0.03	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	749	0.04	0.05	0.02	0.03	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	757	0.03	0.07	0.02	0.01	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	805	0.06	0.04	0.02	0.01	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	813	0.06	0.03	0.03	0.05	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	821	0.02	0.02	0.03	0.05	0.01	8.88	8.88	8.88	8.88	0.03	8.88	8.88	8.88
154	829	0.02	0.	0.01	0.03	0.02	8.88	8.88	8.88	8.88	0.04	8.88	8.88	8.88
154	837	0.01	0.01	0.	0.03	0.01	8.88	8.88	8.88	8.88	0.03	8.88	8.88	8.88
154	845	0.	0.01	0.01	0.02	0.01	8.88	8.88	8.88	8.88	0.04	8.88	8.88	8.88
154	853	0.	0.	0.03	0.02	0.01	8.88	8.88	8.88	8.88	0.04	8.88	8.88	8.88
154	901	0.01	0.	0.03	0.01	0.	8.88	8.88	8.88	8.88	0.02	8.88	8.88	8.88
154	909	0.01	0.01	0.01	0.01	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	917	0.	0.01	0.	0.01	0.02	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	925	0.	0.01	0.	0.	0.01	8.88	8.88	8.88	8.88	0.07	8.88	8.88	8.88
154	933	0.	0.01	0.01	0.01	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	941	0.	0.	0.01	0.01	0.02	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	949	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	957	0.01	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	1005	0.01	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.01	8.88	8.88	8.88
154	1013	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1021	0.	0.	0.	0.	0.02	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1029	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1037	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1045	0.	0.	0.	0.	0.02	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1053	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1101	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1109	0.	0.	0.	0.	0.02	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1117	0.	0.	0.	0.	0.02	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1125	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88
154	1133	0.	0.	0.	0.	0.01	8.88	8.88	8.88	8.88	0.	8.88	8.88	8.88

Fig. A-6 (b). Output of IDH Phase 2 in time series format showing 16-min total rain amount (.01 in.) at 8-min intervals at all mesonetwork stations in the period 0725—1133, 3 June, 1965. The notation 8.88 represents missing data or inoperative stations.

At the user's option the data can be rearranged by the IDH Phase II program to provide a mapped array of simultaneous observations from all stations. Two maps are produced; the station models for each are shown in Fig. A-7. Sample maps are shown in Fig. A-8(a) and (b) for 0715 EST, 3 June 1965. Map 1 [Fig. A-8(a)] contains 4-minute mean values of temperature (T, °C), dew-point temperature (TD, °C), sea-level pressure (P, mb), 4-minute total rain amount (RC, .01 in.), and an indication of whether or not precipitation was detected at each station in the sampling period (RNR). No pressure sensors were installed at Stations 3,4, and 5, at the time the data shown in Fig. A-8(a) were collected. Consequently, the values of mean sea-level pressure at these stations should be ignored since they are simply converted values of reference voltages. Map 2 [Fig. A-8(b)] contains 4-minute mean values of wind direction (DIR) and speed (SPD),

(ID)		T		(ID)	DIR		SPD	(resultant wind)
*		TD		*	DIR		SPD	(peak wind)
		P			CH1		Low 10	Percentile
	RC		RNR			CH2		
						TR		
	MAP 1				MAP 2			

Fig. A-7 Station models used in map format output of IDH - Phase II. Asterisk indicates approximate geographic location of station.

the maximum wind direction and speed recorded in the data sample, median or modal low cloud height (CH1), the median height of all secondary cloud readings (CH2), the low 10 percentile of primary cloud height readings, and the 4-minute mean transmission values (TR). The occurrence and sign of the most recent significant time change in cloud height, wind direction, wind speed, and transmission between maps is indicated by a plus or minus sign following the numerical value of each variable. Quantitative criteria for significant changes are established by optional specification. A summary of the significant changes (not shown here) is printed following Map 2.

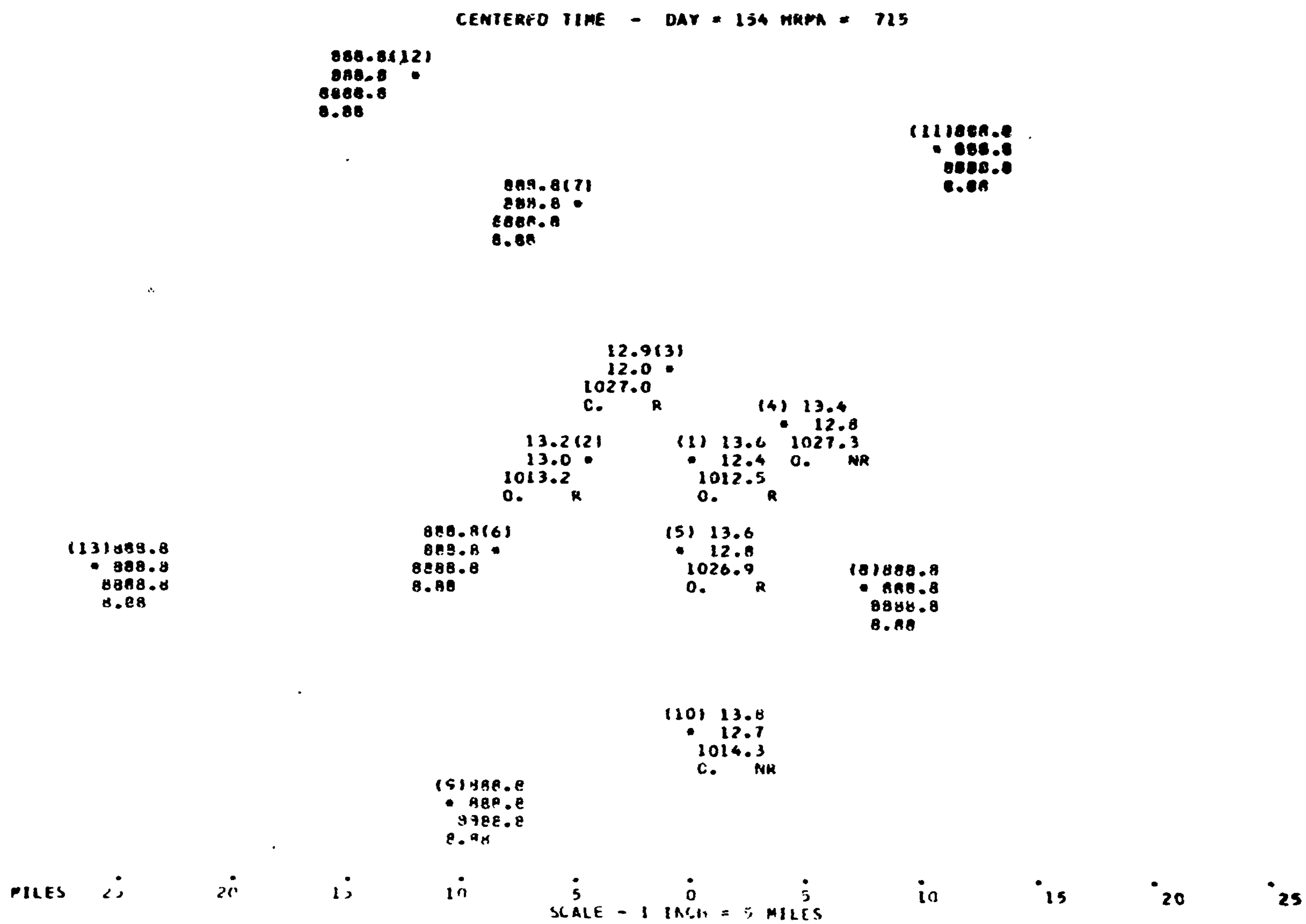


Fig. A-8 (a). Map 1 output from IDH Phase 2 for 0715 EST, 3 June, 1965. The station model is shown in Fig. A-7.

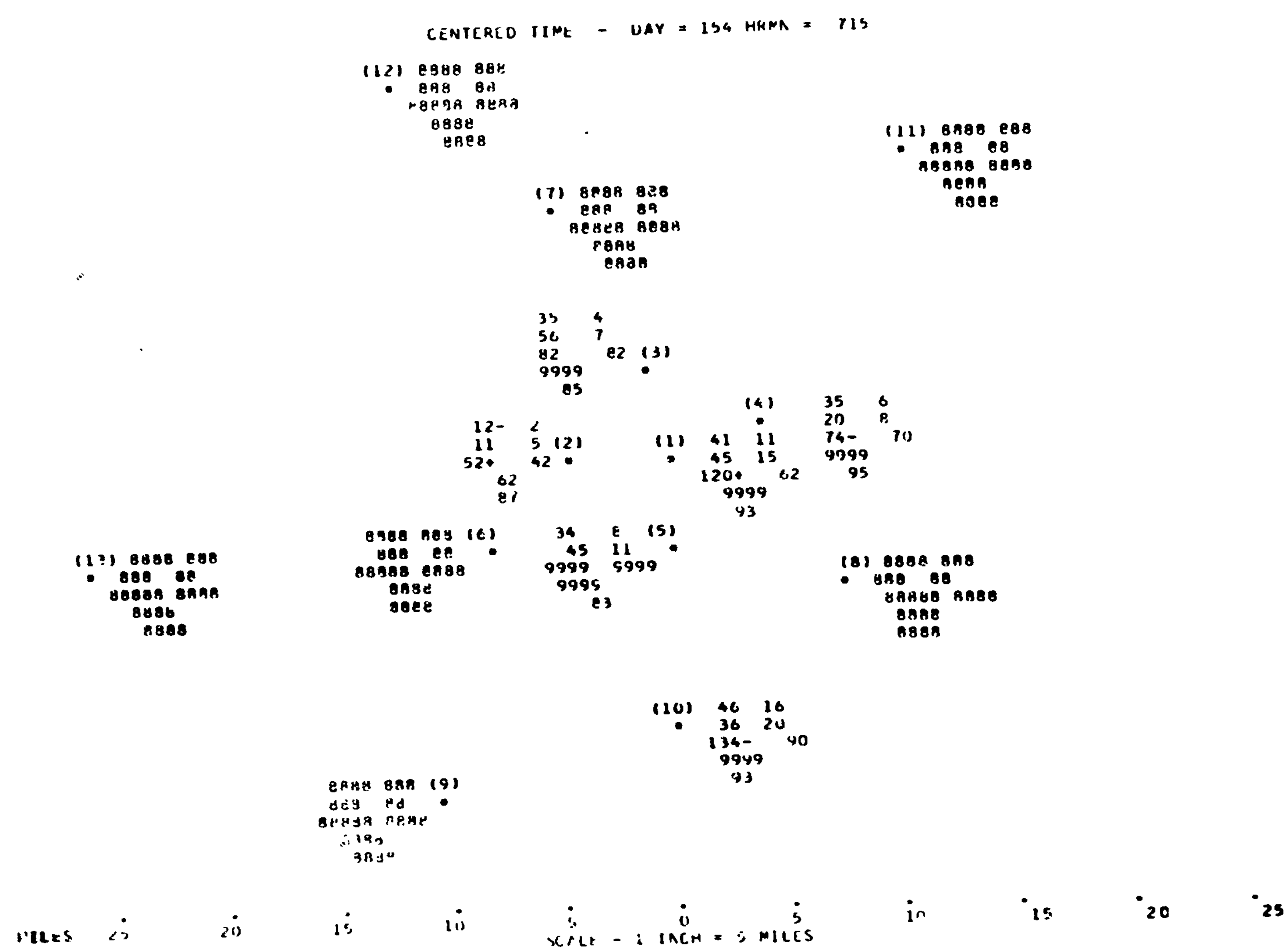


Fig. A-8 (b). Map 2 output from IDH Phase 2 for 0715 EST, 3 June, 1965. The station model is shown in Fig. A-7.

V. TIME-SERIES TRANSLATION PROGRAM

Earlier investigations of transmission observations from instruments separated by distances ranging from 1/4 mi to more than 20 mi showed that occurrences of low transmission occasionally could be identified and followed from one station to another for significant periods of time [2-6] . However, due to lack of observations much of this work was restricted to distances of 3 mi or less and to time periods of about 20 minutes or less. In order to facilitate the data processing required for a more comprehensive study of the movement of patterns of low transmission and low cloud-base height, a time-series translation prediction computer program was prepared.

The Atlantic City mesonetwork weather stations are arranged approximately on 3 rings or circles of radii 5, 10, and 20 mi from Station 1. Because of this arrangement and the small total number of stations (13), no attempt was made in this study to prepare objective analysis programs. Instead, given a translation or movement vector, the computer program selects the nearest station in the direction from which the pattern is thought to be moving at a distance greater than or equal to the distance required for predictions at specified time intervals, assuming that the pattern moves uniformly from the predictor station to the predictand station (Station 1). Time-series observations of transmission or cloud-base height at the predictor station are then compared with later observations at the predictant station. The movement vector can be derived automatically from surface wind observations at Station 1 or specified externally from radar observations, upper-level winds, tower data, or other sources.

A test sample of cloud height data (1650—1922 EST, 13 July 1965) is used to illustrate some of the output from the time-series translation program. In this period, steady southerly surface winds were reported within the mesonetwork. Variable fog and low cloud with a base of 100—200 ft was observed along the shore at Station 10. Inland, at Stations 1, 2, 3, 4, and 5, higher cloud bases near 1000 ft were reported initially followed by a gradual downward trend. There appeared to be some evidence of movement of the cloud base northward from Station 5 to 1 to 3. Data from Stations 5 and 1 are shown in Fig. A-9.

Two forms of error summary, derived from the time-series translation program applied to the test period in Fig. A-9 are shown in Fig. A-10(a) and (b). In the test, 4-minute, modal cloud-base height values were used as input and predictions were made for 3 time periods; FP1 = 16 min, FP2 32 min, and FP3 = 60 min. The forecasts periods FP1, FP2, and FP3 were chosen to be multiples of the basic 4-minute sampling period in order to simplify computations and evaluation. With a specified movement vector of 180 deg at 9 kilowatts and predictand Station 1, the program selected Station 5 as predictor station for FP1, and Station 10 as predictor station for FP2 and FP3. The root-mean-square (rms) errors are shown in the top row of Fig. A-10(a) for all 21 forecasts (forecast cycle time = 4 min) and separately, in the third and ninth rows, for forecasts based entirely on predictor station data. The frequencies (NO.) show that for FP1, all 21 forecasts were obtained from Station 5 data; for FP2, 13 were derived from Station 10; and for FP3, 20 were derived from Station 10. The remaining forecasts needed to complete the total of 21 (i.e., 8 for FP2, and 1 for FP3) were obtained using lagged data at Station 1 (persistence).

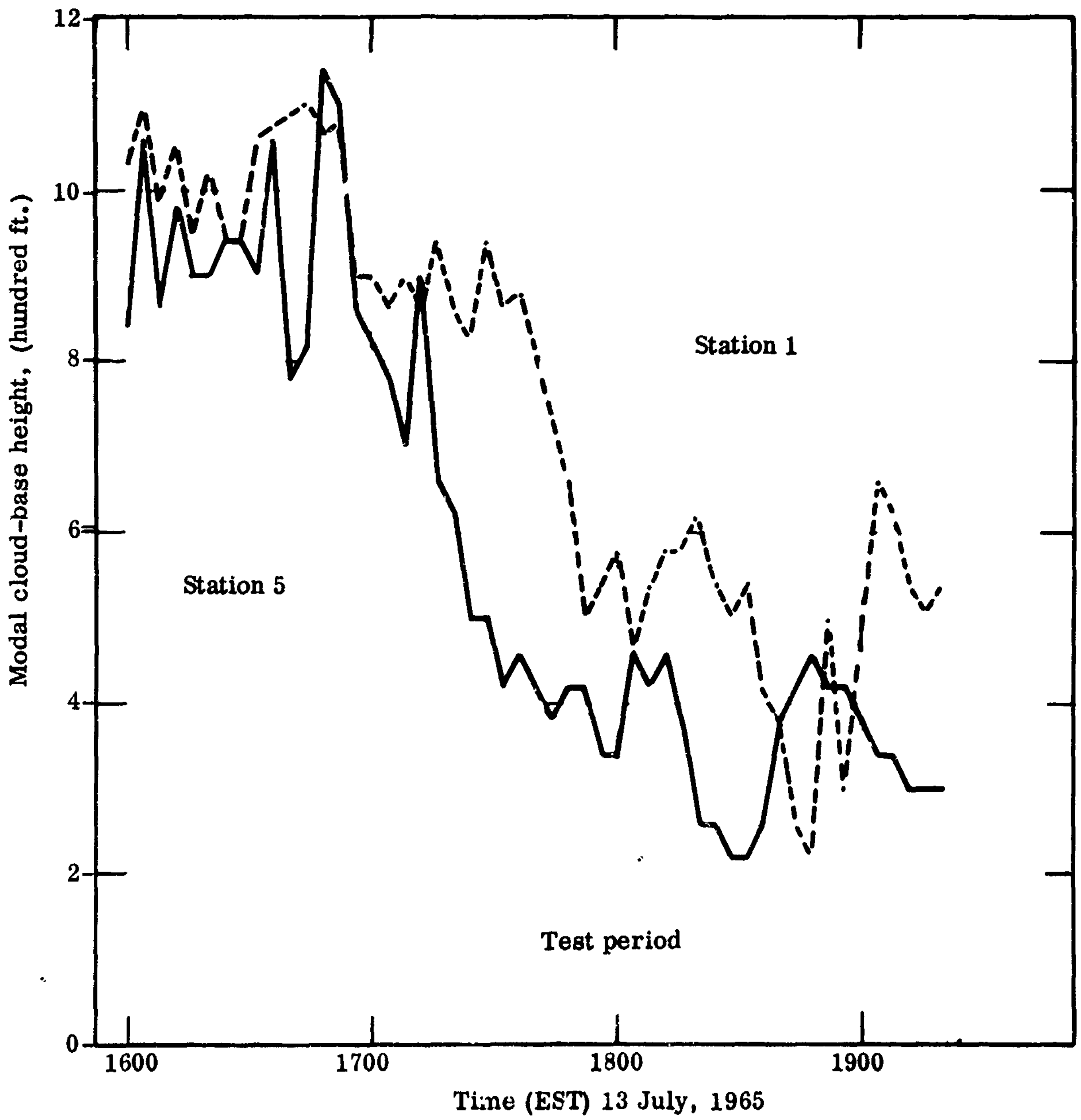


Fig. A-9. Modal cloud-base height observations derived from consecutive 4 min data samples at stations 1 and 5, 13 July, 1965.

ERROR SUMMARY-CLOUD HEIGHT-MODEL-FROM A SPECIFIED VECTOR

STATIONS	RMSE(FP1)	NO.	RMSE(FP2)	NO.	RMSE(FP3)	NO.
1-13	145.6	21.	360.3	21.	414.9	21.
4	0.	0.	0.	0.	0.	0.
5	145.6	21.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.
10	0.	0.	444.5	13.	416.6	20.
11	0.	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.	0.

FP1 = 16. MIN FP2 = 32. MIN FP3 = 60. MIN

ERROR SUMMARY-CLOUD HEIGHT-MODEL FORECAST PERIOD = 16. MIN

CLOUD HEIGHT(FT)	TOTAL NO.	NUMBER OF ERRORS-GROUPED ACCORDING TO ERROR SIZE(FT)											
AT VERIFICATION TIME	OCCURRENCES	0.0-50.0		50.1-100.0		100.1-200.0		200.1-400.0		400.1-800.0		800.1-UNL	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
0. -300.0	0	0	0	0	0	0	0	0	0	0	0	0	0
300.1 -600.0	7	2	0	0	0	5	0	0	0	0	0	0	0
600.1-1000.0	14	7	1	2	0	5	2	1	1	0	0	0	0
1000.1-1500.0	0	0	0	0	0	0	0	0	0	0	0	0	0
1500.1-2500.0	0	0	0	0	0	0	0	0	0	0	0	0	0
2500.1-9999.0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. A-10. Root-mean-square (rms) error summary for three forecast periods FP1, FP2, and FP3 using predictand station 1, and predictor stations 5 and 10 with a specified translation vector of 180 deg at 9 knots for cloud-base height observations in the period 1650—1922 EST, 13 July, 1965 (a). A summary of individual errors for FP1 is given in the lower table (b).

A detailed summary of individual errors according to the absolute cloud-base height, error sign and error magnitude is shown in Fig. A-10(b). For comparison, summaries of root-mean-square errors and individual errors for the same test period using lagged data at Station 1 (persistence) as predictor data are shown in Fig. A-11(a) and (b). The top rows of Figs. A-10(a) and A-11(a) show that the use of Station 5 as a predictor station for 16-minute periods with the specified movement vector resulted in a small improvement over persistence on the basis of root-mean-square error. However, Station 10, with quite different cloud heights, was of no value as a predictor station in this case.

Error summaries similar to those shown in Figs. A-10(b) and A-11(b) are computed for FP2 and FP3 as well as for FP1. Any station within the mesonetwork can be selected as a predictor station and the computations can be carried out for transmission as well as for cloud-base height data. The program is, of course, a true prediction model only if the translation vector is derived from present or past observations or from some other prediction system. At the present time it is intended for both diagnostic studies and prediction tests.

ERROR SUMMARY-CLOUD HEIGHT-PERSISTENCE

RMSE(FP1)	NO.	RMSE(FP2)	NO.	RMSE(FP3)	NO.
159.2	21.	211.6	21.	359.6	21.
FP1 = 16. MIN		FP2 = 32. MIN		FP3 = 60. MIN	

ERROR SUMMARY-CLOUD HEIGHT-PERSISTENCE FORECAST PERIOD = 16. MIN

CLOUD HEIGHT(FT) AT VERIFICATION TIME	TOTAL NO. OCCURRENCES	NUMBER OF ERRORS-GROUPED ACCORDING TO ERROR SIZE(FT) 0.0-50.0		50.1-100.0		100.1-200.0		200.1-400.0		400.1-800.0		800.1-UNL	
		LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH
0. -300.0	0	0	0	0	0	0	0	0	0	0	0	0	0
300.1 -600.0	7	3	0	0	0	0	2	0	2	0	0	0	0
600.1-1000.0	14	4	1	1	2	1	5	0	0	0	0	0	0
1000.1-1500.0	0	0	0	0	0	0	0	0	0	0	0	0	0
1500.1-2500.0	0	0	0	0	0	0	0	0	0	0	0	0	0
2500.1-9999.0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. A-11. Root-mean-square (rms) error summary for three forecast periods FP1, FP2, and FP3 using predictand station 1, and predictor station 1 (persistence) for cloud-base height observations in the period 1650—1922 EST, 13 July, 1965 (a). A summary of individual errors for FP1 is given in the lower table (b).

APPENDIX B. MESONETWORK DATA ANALYSES

I. INTRODUCTION

Following activation of the center mesonetwork station (1) and the four closest stations (2, 3, 4, 5), data collection was initiated in May, 1965 by U.S. Weather Bureau personnel at NAFEC during weather conditions of particular interest to aviation terminal operations. In subsequent months additional stations were activated on completion of thorough checkout and calibration procedures. By 20 August 1965, 8 stations were in operation and 27 data collections had been completed. Appendix B describes some preliminary analyses of these data with emphasis on aspects of data quality such as reliability, relative and absolute accuracy, representativeness, noise levels, etc., and on the adequacy of the data processing techniques described in Appendix A. No consideration of pressure data is included since a change in instrument is planned for late 1965.

II. DATA LOG

During the present experimental phase the mesonetwork functioned discontinuously, yielding discrete data samples. The general requirements were for data samples immediately preceding, during and immediately following occurrences of low visibility, low cloud, heavy precipitation, strong winds, and gusty winds or shifts in wind direction. The question of bias due to unsampled events or unsampled onsets of events is not considered in the report because the mesonetwork was not fully staffed in the first months of operation.

A complete list of data samples for the period 20 May to 20 August, 1965 is given in Table B-I. The durations of low cloud and low meteorological visual range events based on 4-minute averages at Station 1 are listed in the last rows of the table. The visual range information was derived from transmission data using empirical day and night conversion curves [7].

TABLE B-I
LOG OF ATLANTIC CITY MESONETWORK DATA COLLECTIONS
20 May — 20 August, 1965

No.	Date	Time period (EST)	No. stations	Sample size (min)	Duration of low cloud (H) at station 1 (minutes)		Duration of low meteorological visual range (V) of Station 1 (minutes)	
					H ≤ 1000 ft	H ≤ 200 ft	V ≤ 1 mi	V ≤ 1/2 mi
1	20 May	0507—0647	5	100	0	0	0	0
2	21—22 May	1434—1016	6	1164	992	0	0	0
3	24 May	0512—1155	6	403	0	0	0	0
4	27 May	1428—2159	6	451	0	0	0	0
5	3 June	0710—1133	6	263	76	0	0	0
6	15—16 June	2130—1921	7	1311	0	0	0	0
7	6 July	0530—0813	6	163	4	0	36	28
8*	7 July	0324—0657	7	—	—	—	—	—
9	7—8 July	1830—0613	7	703	168	0	0	0
10	9 July	0330—0857	7	327	0	0	0	0
11	11 July	1020—1927	7	547	384	4	0	0
12	12 July	0520—0739	7	139	0	0	0	0
13	13 July	0522—1100	7	338	88	0	64	52
14	13—14 July	1510—0729	7	979	600	208	80	32
15	17—18 July	1440—0900	7	1100	568	28	0	0
16	18—19 July	1509—0657	7	948	48	48	0	0
17	30 July	0528—0815	6	167	0	0	44	36
18	1—2 Aug	1330—0829	8	1139	4	4	0	0
19	5—6 Aug	2024—0859	8	755	4	4	448	408
20	6—7 Aug	2220—0951	8	691	0	0	0	0
21	9—10 Aug	2148—0827	8	639	0	0	0	0
22	13 Aug	0530—0929	8	239	0	0	100	92
23*	16 Aug	0515—0900	8	—	—	—	—	—
24	16—17 Aug	2204—0747	8	583	0	0	0	0
25	17—18 Aug	2130—0754	8	624	0	0	152	136
26	19 Aug	0516—0859	7	223	0	0	0	0
[illegible]	19—20 Aug	1344—0703	8	1039	0	0	0	0
TOTALS				15055	2936	296	924	784

* Data processing incomplete

III. ANEMOMETER DATA

Each mesonetwork station is located within a cleared controlled area of standard dimensions (400 by 900 ft). However, the proximity to the cleared area of forests and other obstructions varies from station to station and varies with direction at particular stations. Possible effects on wind speeds of local exposure conditions were investigated using mesonetwork data and hourly airways observations from Atlantic City (ACY) and Millville (MIV).

In a preliminary study of the exposure problem wind speed observations at Mays Landing (Station 2) at the standard mesonetwork anemometer level (22 ft above ground) were compared with observations from the 48-ft level at the same location and with hourly observations at ACY. The first comparison was based on 60 sample means for time periods of 10 minutes to 6 hours in which the wind speed at the top level exceeded 2 knots. The samples were divided into NE winds (from directions clockwise from 315° to 135°) and SW winds (from directions clockwise from 135° to 315°). Forested areas are closest to the anemometers at Mays Landing along the former directions. The results are shown in the upper part of Table B-II (a). In all cases the mean wind at the upper level exceeded that at the lower level, but in 80 percent of the cases the difference was only 2 knots or less. The results for the two directions separately were very similar.

The second comparison was based on 245 five-minute mean wind speeds from the 48-ft anemometer at Mays Landing and simultaneous hourly airways observations of wind speed from ACY (20-ft runway anemometer). The comparison is shown in the lower part of Table B-II (b). The wind speeds at ACY exceeded those at Mays Landing in 98 percent of the samples. Indeed, in almost 50 percent of the samples, the difference exceeded 4 knots. There was no indication of a significant difference between NE and SW winds.

It can be argued that the hourly airways observations of wind speed represented averages over something less than 5 minutes and that the mesonetwork and hourly observations were not necessarily simultaneous. To overcome these objections and to investigate exposure problems at other mesonetwork stations, a more extensive comparison was made using data from a well-exposed mesonetwork station (Station 10). Wind-speed data samples were selected only for periods in which steady winds were observed at ACY, MIV, and Station 10, and in which data were available from each of Stations 1, 2, 3, 4, 5, and 10. Average wind speeds from 20 sampling periods are shown in Table B-II (b). In the center columns of the table the wind speeds are grouped by quadrants. Averages for all wind directions are listed by station in the last column on the right. At Stations 1, 2, 3, 4, and 5 the average wind speeds for all directions range from about 1/3 to 1/2 of the average speeds at ACY, MIV* and Station 10. At some stations the differences are larger for particular wind directions. In general the largest departures from the expected wind speeds are found with wind directions from the most severely obstructed quadrant at individual stations. At Station 3, for example, oak and pine forests 35 to 50 ft high begin 120 to 200 ft northeast, north, and northwest of the anemometer. Rows of thinly distributed trees are located 150 — 200 ft southwest, and the most open exposure occurs for south-southwest to south-southeast wind directions. This distribution suggests that the local forested areas, even though at least 120 ft distant, resulted in substantial reductions in mean wind speed at anemometer level

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* ACY and MIV are denoted No. 14 and No. 13, respectively, on Fig. I-1.

TABLE B-II (a)
WIND SPEED COMPARISONS AT TWO LEVELS AT MAYS LANDING AND
BETWEEN MAYS LANDING AND ATLANTIC CITY (ACY)

WIND SPEED, knots	NE Wind	SW Wind	All cases	
	Number of samples	Number of samples	Number of samples	Percent of total
$V_{M2} - V_{M1} \leq 2$	15	33	48	80
$V_{M2} - V_{M1} > 2$	5	7	12	20
$V_{A1} - V'_{M2} > 0$	100	141	241	98
$V_{A1} - V'_{M2} > 4$	53	68	121	49
$V_{A1} - V'_{M2} > 6$	20	36	56	25

V_{M1} - mean wind speed at Mays Landing (22-ft level)

V_{M2} - mean wind speed at Mays Landing (48-ft level)

V_{A1} - hourly airways observation of wind speed at Atlantic City (20-ft level)

V'_{M2} - 5-min. mean wind speed at Mays Landing (48-ft level)

Assuming that these data are correct, and there appears to be no valid reason to think that they are not, the existence of appreciable local effects on wind poses serious analysis problems. For the purpose of computing divergences of the air flow, or for the analysis of mesoscale disturbances, wind data are needed that are representative of distance scales comparable to station spacing, rather than characteristic of the immediate station environment. On the other hand, for the analyses of local fog formation and dissipation, data representative of the clearings are likely to be more appropriate. In view of this conflict of interests, the feasibility of correcting short-period mean wind speed observations by individual stations and wind directions should be investigated before any attempt is made to measure winds that are representative of somewhat larger space scales. On the basis of data now available there appears to be no evidence of large systematic differences in wind direction associated with the observed differences in speed. At times, however, because of the large anemometer starting speed (about 3 knots), intervals of calm winds (that cannot be corrected to values representative of mesoscale conditions) occur at the most severely obstructed stations in periods with non-zero winds at other stations.

TABLE B-II(b)
COMPARISON OF MEAN WIND SPEEDS AT MESONETWORK AND OTHER LOCAL STATIONS IN PERIODS OF STEADY WIND CONDITIONS AT ATLANTIC CITY (ACY), MILLVILLE (MIV), AND STATION 10

Station	Wind direction and velocity, knots				
	NE (4 samples)	SE (4 samples)	SW (7 samples)	NW (5 samples)	All (20 samples)
MIV	8.8	10.2	8.7	7.9	8.8
ACY	9.1	10.8	9.1	8.6	9.3
1	6.3	3.9	3.2	5.8	4.6
2	2.0	4.9	3.6	2.8	3.3
3	2.2	5.0	3.3	1.5	3.0
4	4.2	4.2	3.1	2.5	3.4
5	4.7	4.4	3.9	3.9	4.2
10	8.7	7.1	6.3	7.1	8.2

IV. ROTATING-BEAM CEILOMETER OBSERVATIONS

In the rotating-beam ceilometer system, light returned to the earth's surface from the atmosphere is detected by a fixed vertically-pointing photoelectric cell. Peak detector circuits are used to identify up to two maxima above a specified noise level in the return signal. Tangents of the projector angles corresponding to each maximum are recorded so that the height of the obstructions can be obtained by simple trigonometry. In the Atlantic City mesonetwork projector beam tangents corresponding to peak signals are recorded every 12 seconds at each station. In the data processing program (IDH Phase II) these tangents are converted to heights, and the frequency distributions of heights in sample periods of a few minutes or longer are used to obtain median or modal values and the lowest 10 percentiles. The precise rules by which these calculations are performed are described in the specifications for the IDH Phase II computer program [8] .

The original and derived heights obtained from rotating-beam ceilometer measurements of a well-defined cloud base are shown in Fig. B-1. In this sample the height observations were tightly clustered and the modal and 10 percentile values were almost identical. The smoothing inherent in the derived heights appeared to be reasonable. Three isolated low readings were observed. It should be noted that such readings could be due to cloud fragments of up to 700 ft in diameter if the fragments are moving at a speed of 20 mph.

Sample observations of an ill-defined cloud base are shown in Fig. B-2. The separation of the modal and low 10-percentile values provided a useful indication of the magnitude of the short-period variability in cloud-base height.

A drop in cloud height due to the arrival or formation of a second layer is illustrated in Fig. B-3. Although the derived cloud heights provide a reasonable summary of the height information, they fail to show that the change in cloud height from 0550 to 0554 EST was due to the appearance of a new layer rather than to the change in height of a single layer as shown, for example, in Fig. B-1. Modifications to the IDH Phase II program, utilizing both first and second subcycle cloud height measurements, are needed to avoid the loss of information on the layer structure of clouds.

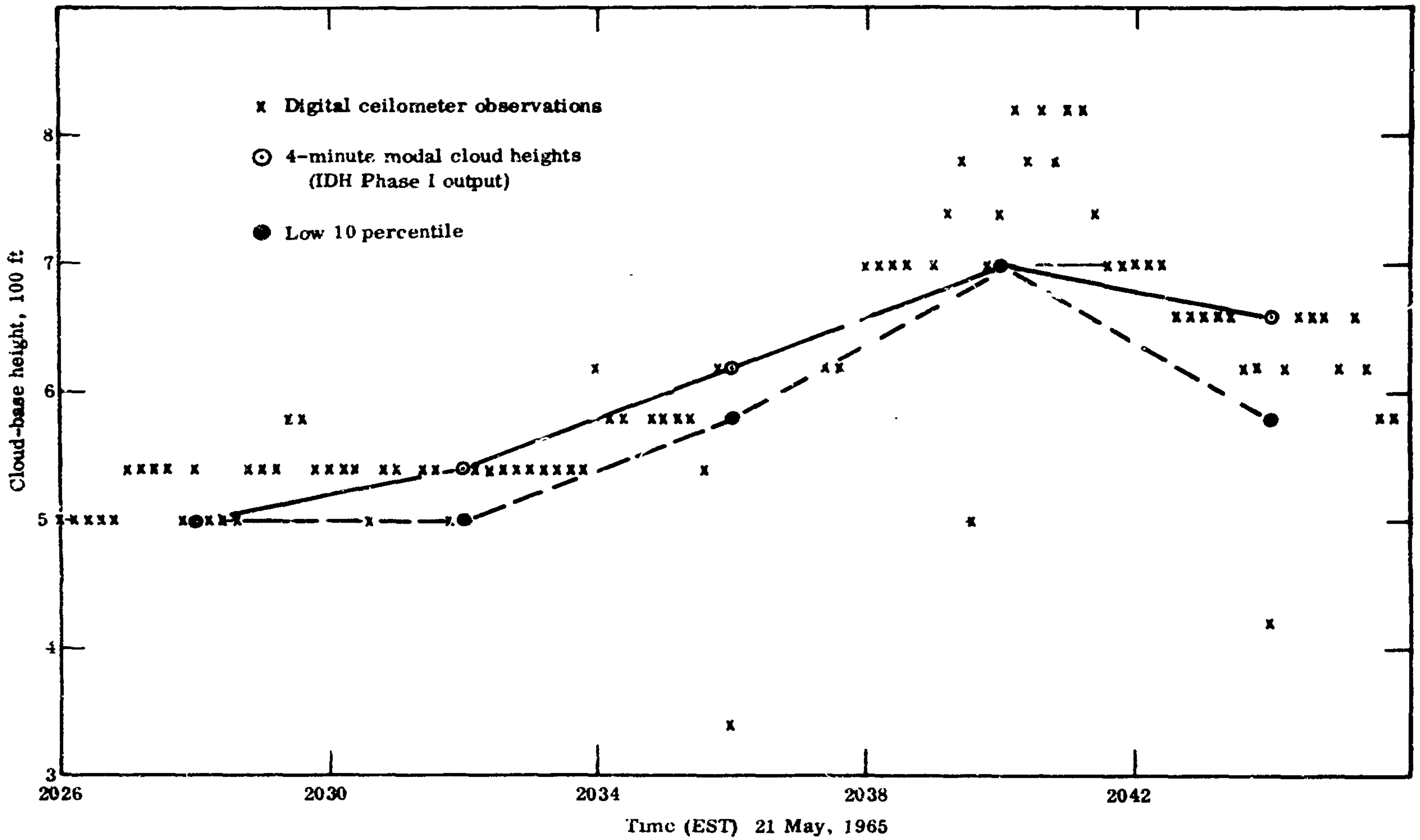

Fig. B-1. Original and derived cloud-base heights obtained from rotating-beam ceilometer observations at station 1 on 21 May, 1965.

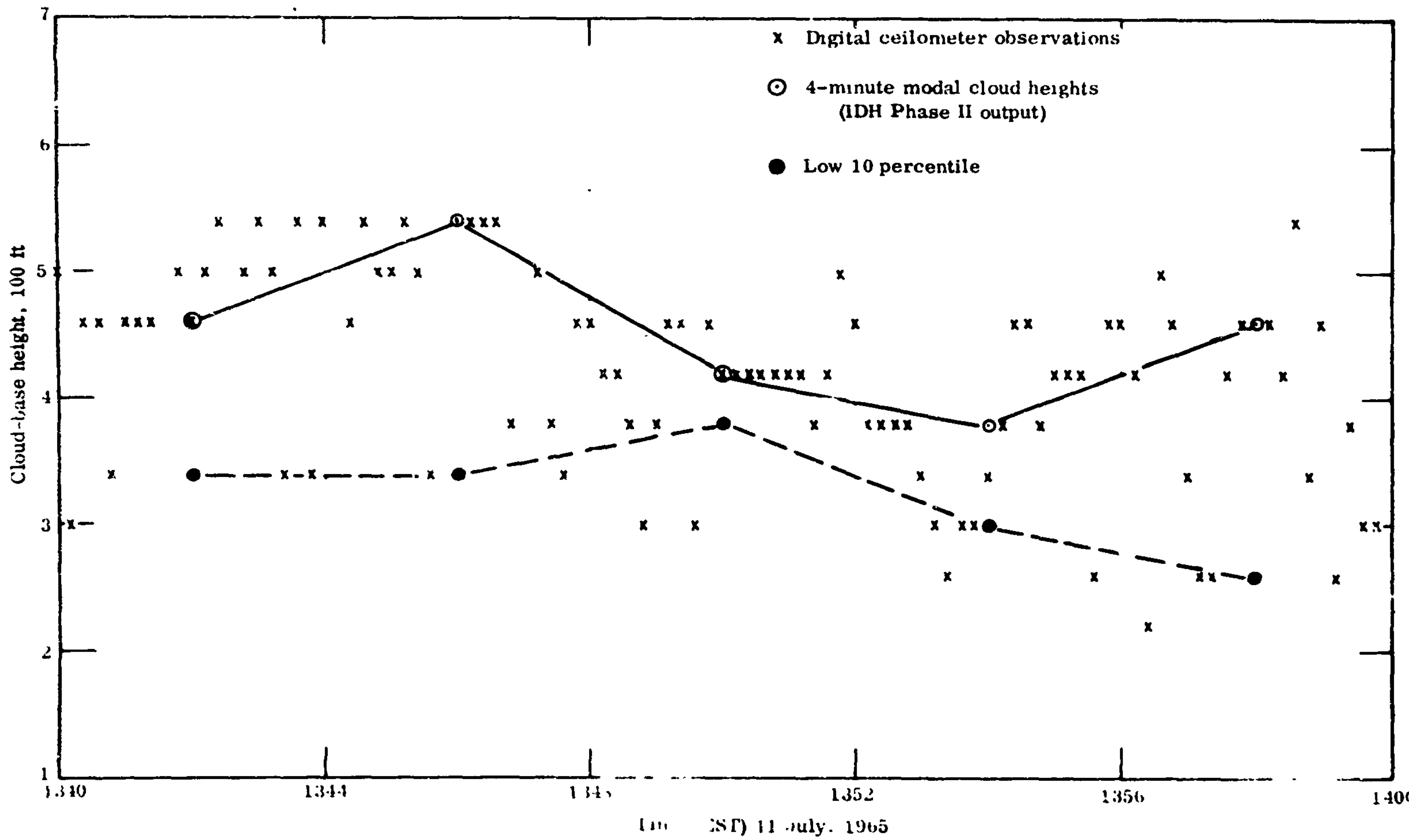

Fig. B-2. Original and derived cloud-base heights obtained from rotating-beam ceilometer observations at station 1 on 11 July, 1965.

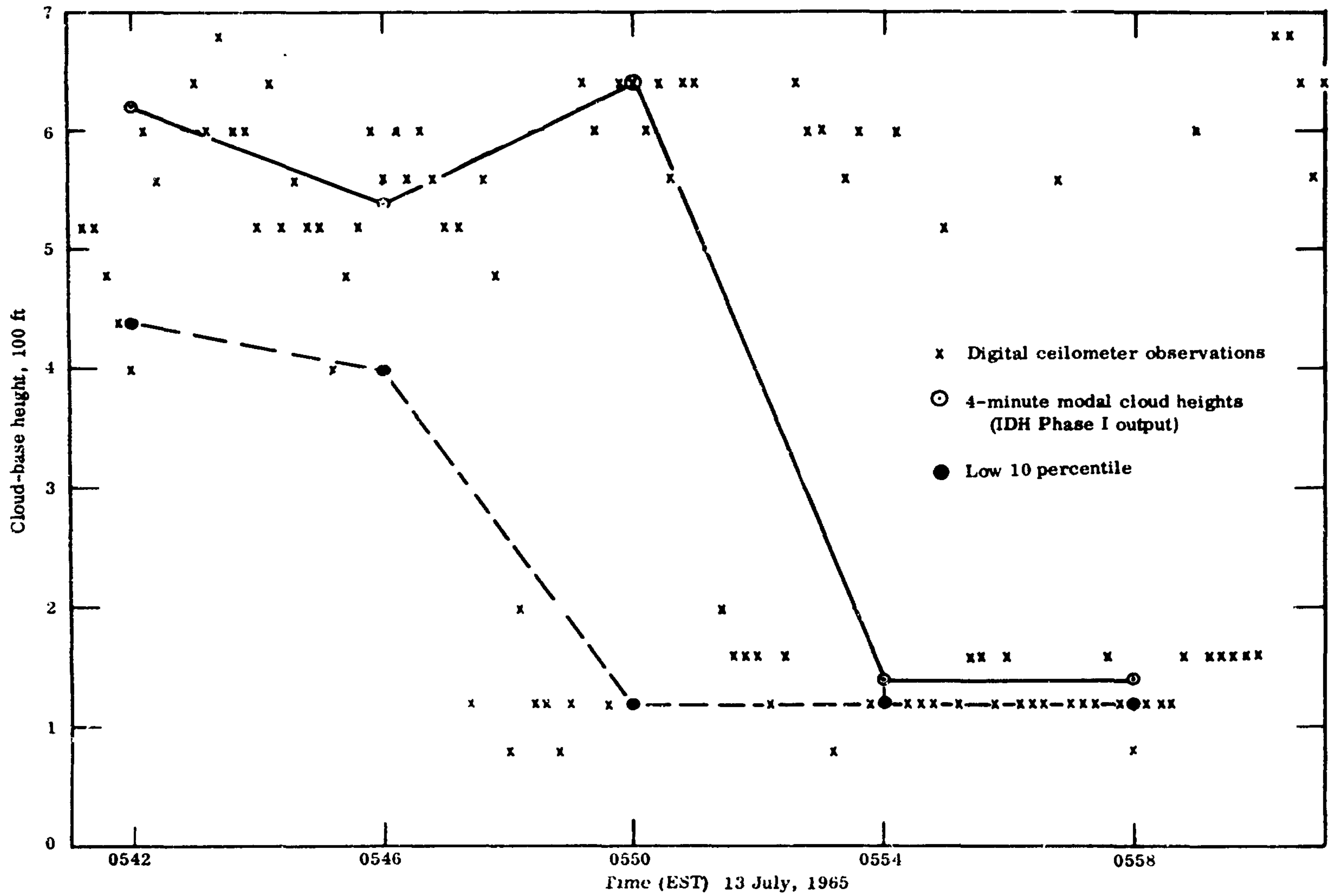

Fig. B-3. Original and derived cloud-base heights obtained from rotating-beam ceilometer observations at station 2 on 13 July, 1965.

V. INTERPRETATION OF CLOUD HEIGHT OBSERVATIONS

Some typical examples of raw cloud height observations and the heights derived from these observations by the data processing programs were described and illustrated in section IV. However, these comparisons provided no information on the question of whether or not the derived heights were physically meaningful reference points in the clouds. Although much more investigation is needed before a comprehensive answer can be given to this question some preliminary information has been obtained from concurrent cloud height, temperature, and dew-point measurements.

Simultaneous 4-minute modal cloud heights and 4-minute mean dew-point speeds ($T-T_d$) at Station 1 on 21 May, 1965, in a period of low cloud without precipitation, are shown in Fig. B-4. During this period numerous fluctuations in cloud height occurred with a slow upward trend. The cloud base was that of a single well-defined layer. The brief period of large height change at about 2030 EST was illustrated in detail previously in Fig. B-1.

Inspection of Fig. B-4 shows little or no correspondence between 4-minute changes in dew-point spread and 4-minute changes in modal cloud height. However, longer-period trends, such as the drop in dew-point spread from 2002 to 2034 EST and the slow rise in average dew-point spread from 2100 to 2330 EST, were accompanied by corresponding trends in cloud height. This is illustrated more clearly by twenty-minute running averages 4 minutes apart in Figure B-5. Here, although the overall correlation was far from perfect, the largest and most persistent changes in dew-point spread and cloud height were fairly similar. Systematic calibration errors in the observations can be eliminated by considering only the simultaneous time changes in cloud-base height and dew-point spread. Twenty-minute changes (at 4-minute intervals) of the 20-minute mean cloud heights and dew-point spreads are shown in Figure B-5(b) for the data that were used in Figs. B-4 and B-5(a). With the exception of the period from about 2058 to 2138 EST, the two curves are fairly similar.

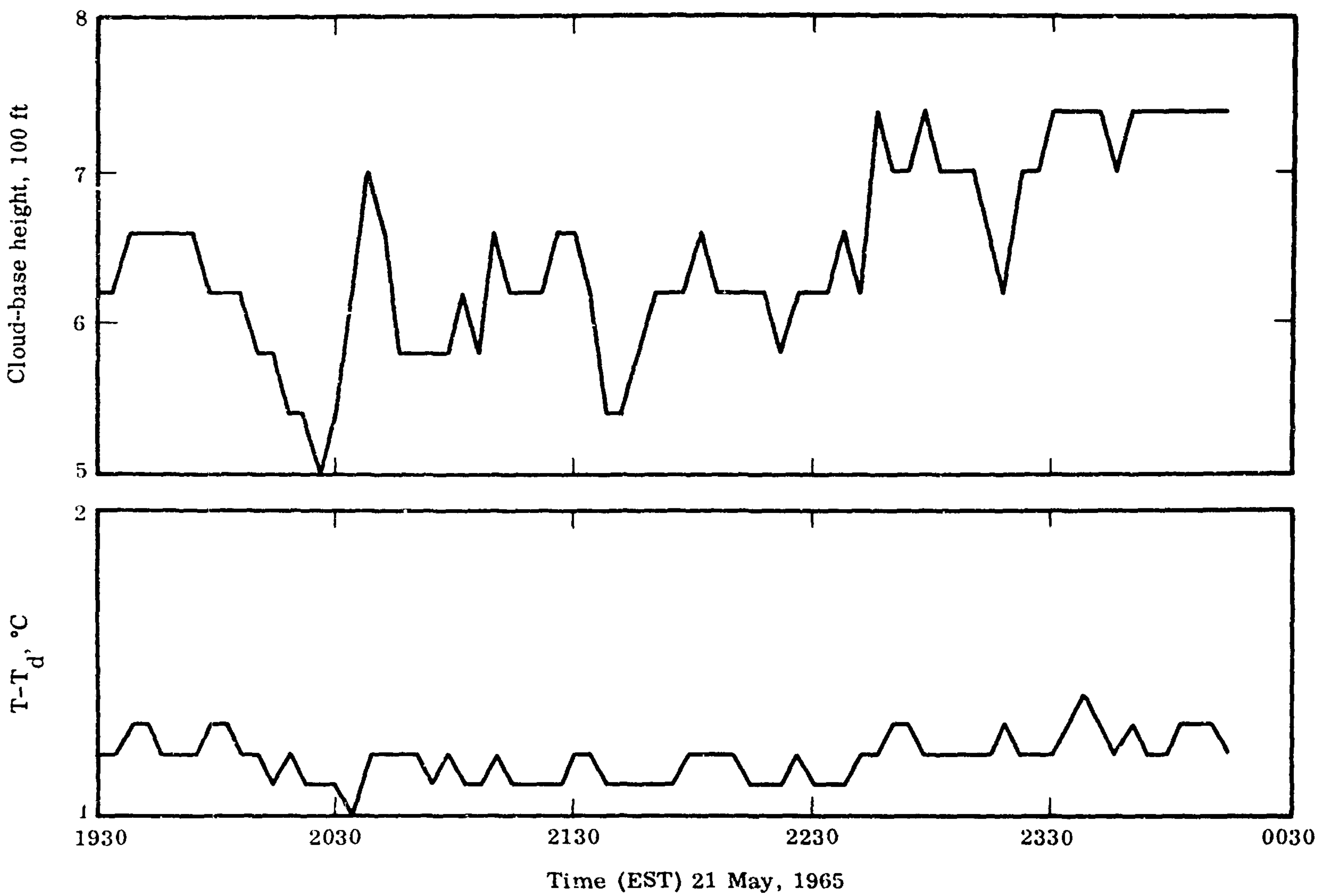

Fig. B-4. Simultaneous 4-minute modal cloud heights and 4-minute mean dew-point depressions at station 1 on 21 May, 1965.

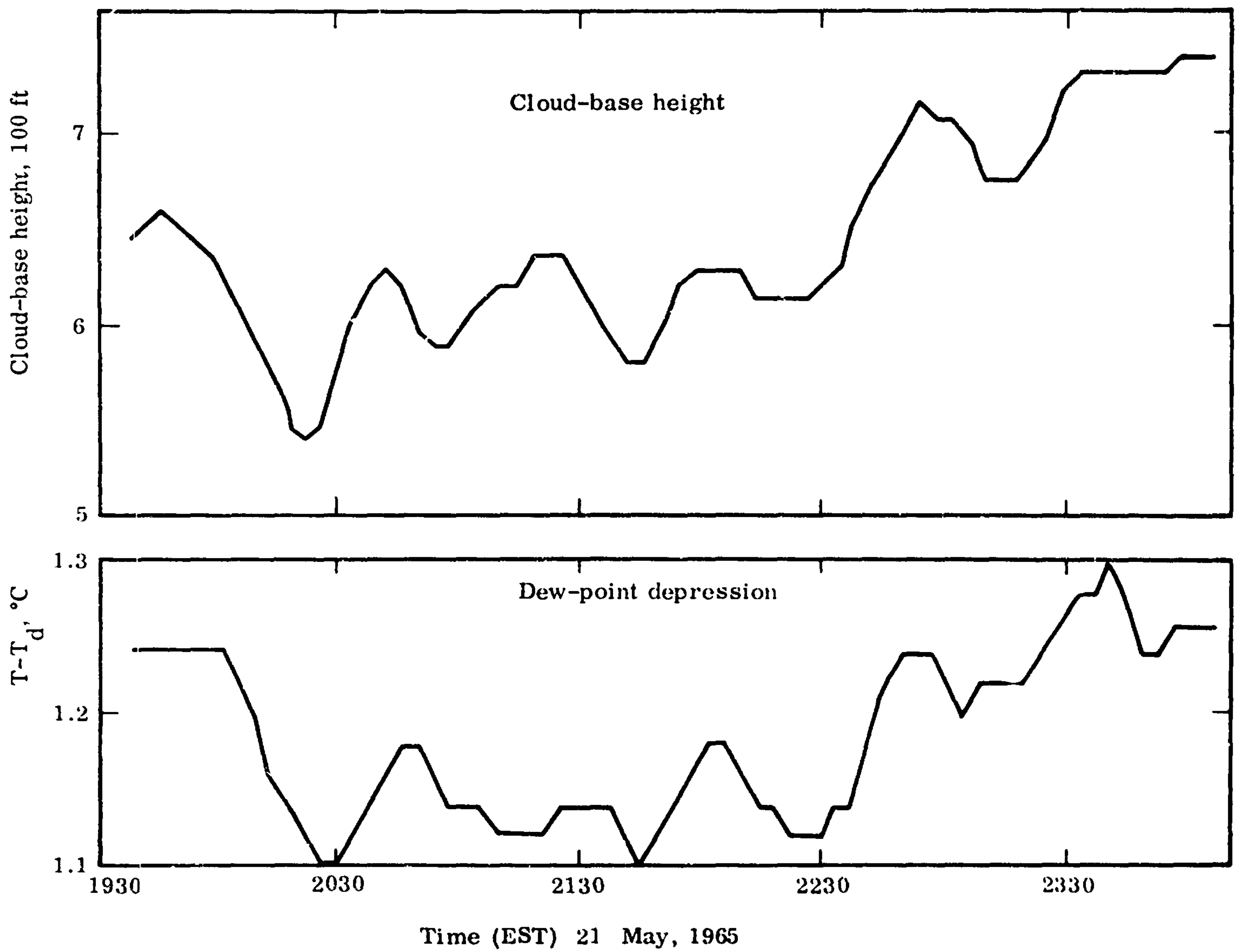

Fig. B-5 (a). Twenty-minute running mean cloud heights and dew-point depressions at station 1 on 21 May, 1965.

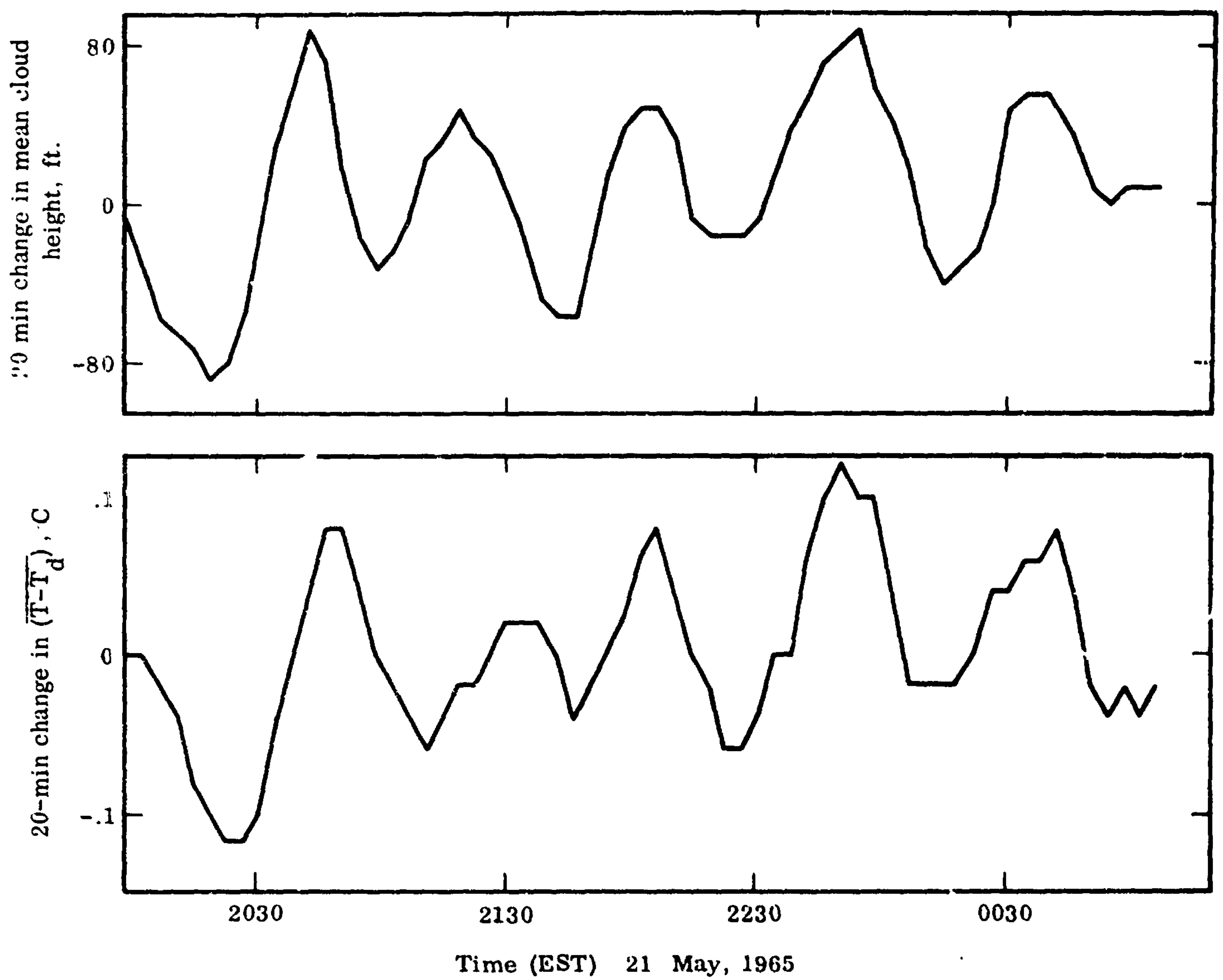

Fig. B-5(b). Simultaneous 20-minute changes in 20-minute mean cloud height (upper curve) and 20-minute mean dew-point spread (lower curve) on 21 May, 1965.

VI. TEMPERATURE AND DEW POINT OBSERVATIONS IN PRECIPITATION

Additional useful information on the physical significance of observed changes in temperature and dew-point temperature can be derived from observations immediately preceding, during, and following precipitation. The onset of precipitation in unsaturated air should result in evaporation accompanied by a decrease in air temperature and an increase in dew-point temperature. The mesonetwork observations do indeed show such changes during the onset of precipitation at individual stations. The interpretation of these data is greatly facilitated by observations from the rain detector since the threshold of this instrument for detection of precipitation is evidently lower than the threshold of the tipping bucket gages.

On 27 May, 1965 two brief showers were reported at Station 4 between 1730 and 1800 EST. The temperature, dew point, and precipitation observations for this period are shown in Fig. B-6. The first shower (1730—1733) was not detected by the tipping bucket gage; the second (1742—1751), however, produced 0.27 inches at gage level. Both were accompanied by decreasing temperatures and increasing dew points. For several minutes following each shower the dew point remained steady, suggesting either the arrival of surface air moistened elsewhere by the same shower, sensor lag, or both. The air temperature continued to fall after the rain ended at Station 4, to a minimum at about 1753 EST.

The showers at Station 4 were apparently associated with a squall line that crossed the mesonetwork from west to east. Thunderstorms were reported at both Millville and Philadelphia but, although the wind shifted to northwest at the westernmost station available in the network (Station 2), no rain was reported. The changes in temperature and dew point accompanying the windshift at Station 2 are shown in Fig. B-7. The striking feature of Fig. B-7 is the sharp drop in dew point that occurred at the leading edge of the cool air. Subsequent observations at other stations to the east in the mesonetwork indicated that this pool of cool dry air (possibly a thunderstorm-generated cold dome) moved eastward much more slowly than the wind-shift line.

The data in Figs. B-6 and B-7 show low "noise" levels probably not exceeding ± 0.2 to $\pm 0.3^{\circ}$C in the raw observations of both temperature and dew point. Further, both sensors responded rather quickly (not more than 1 to 3 minutes) to changes of the order of 1 to 3°C.

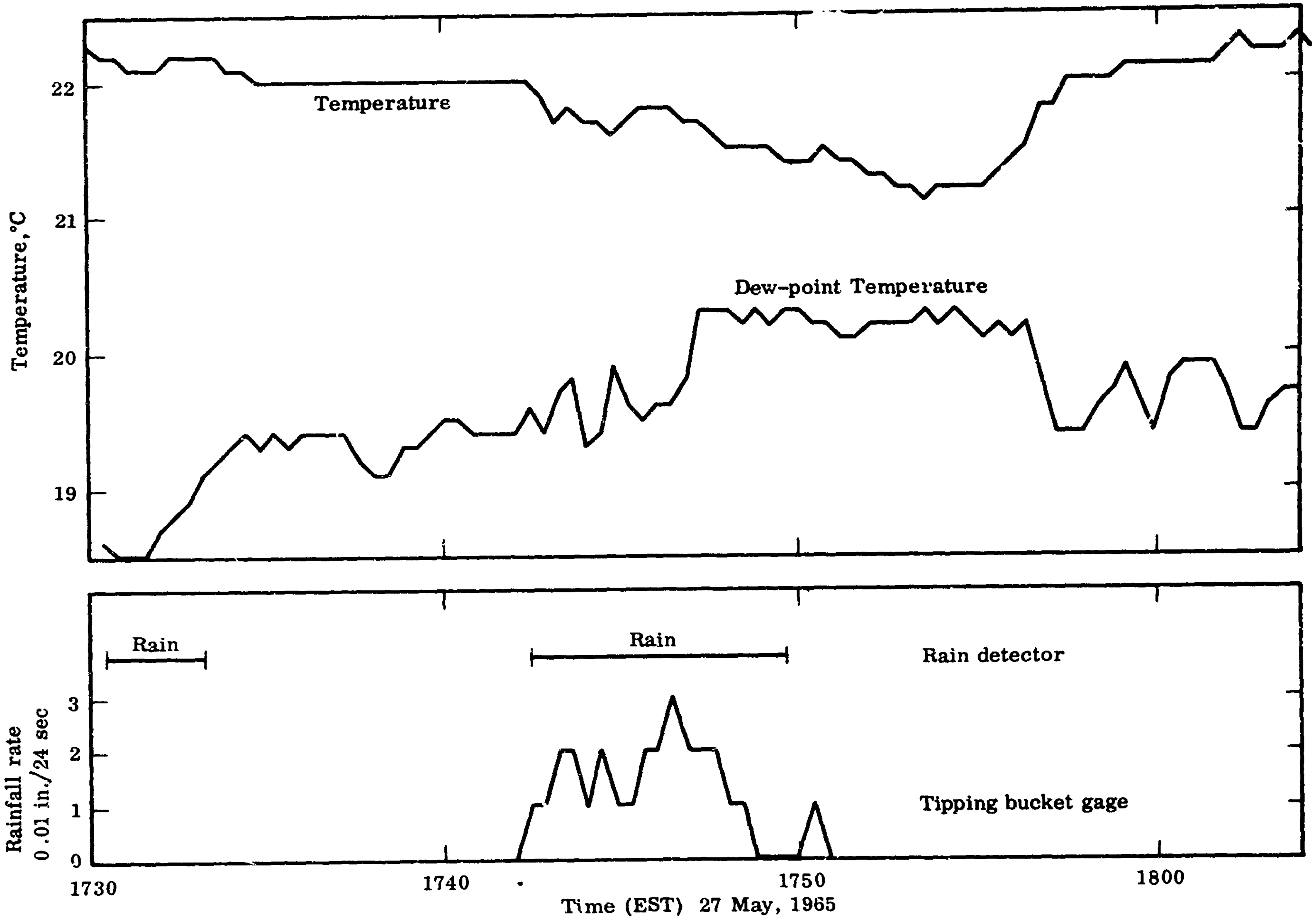

Fig. B-6. Simultaneous temperature, dew point, and precipitation observations at 24-second intervals in showers at station 4 on 27 May, 1965.

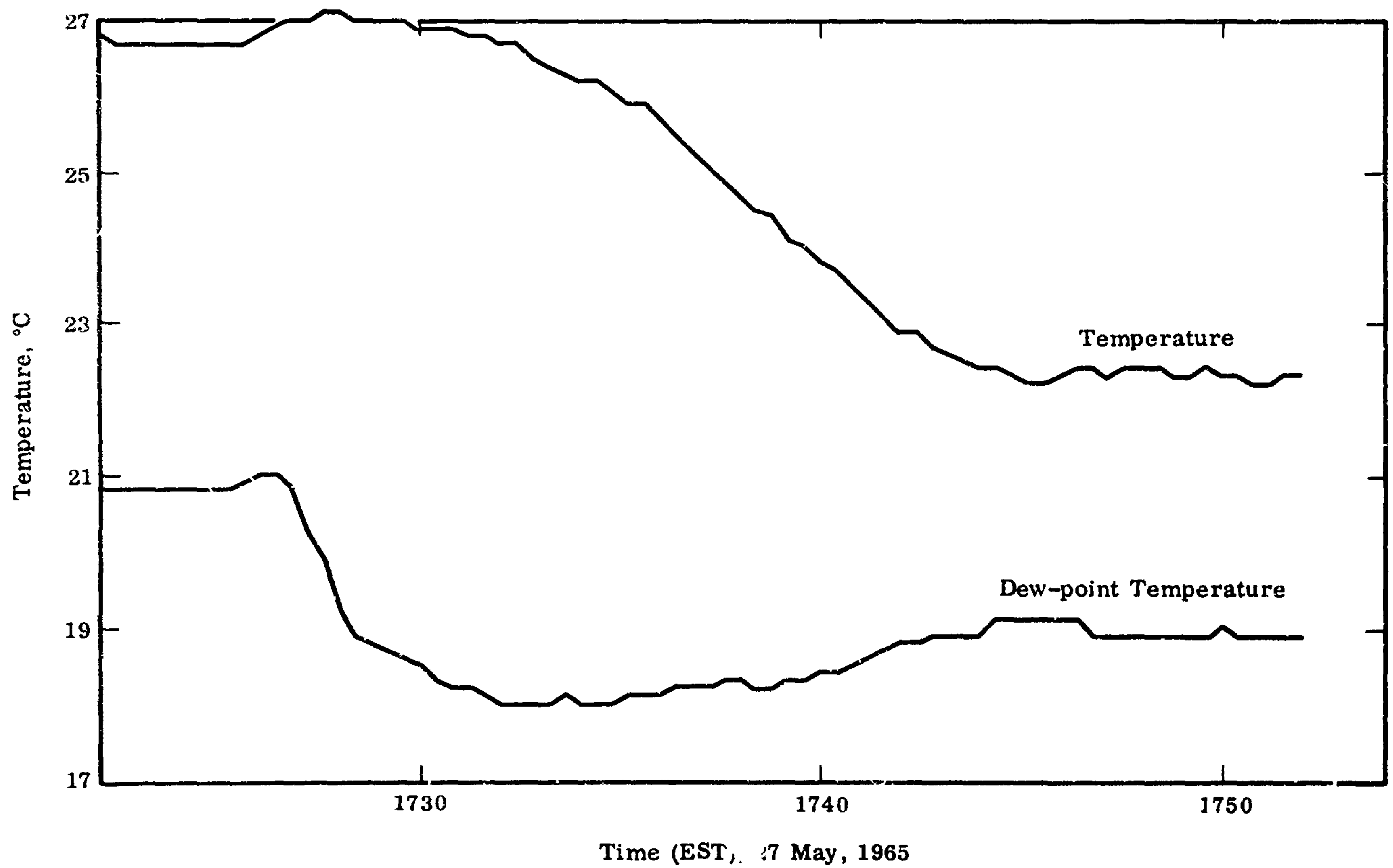

Fig. B-7. Simultaneous temperature, dew-point, and precipitation observations at 24-second intervals at station 2 on 27 May, 1965.

VII. TRANSMISSION OBSERVATIONS IN PRECIPITATION

As noted in an earlier study of fragmentary mesonetwork data [4], occurrences of measurable rainfall (as recorded by the tipping bucket gages) were accompanied by simultaneous reductions in transmission when the transmission was not already reduced by some other obstruction. Such occurrences provide additional evidence of proper performance of the transmissometer, tipping bucket gage, and rain detector components of the system. Transmission data from Station 4 during the two showers described in the preceding section are shown in Fig. B-8. The reduction in transmission in this case appears to be due entirely to rain. This is but one of many examples of this type found for each station in the 27 data collections.

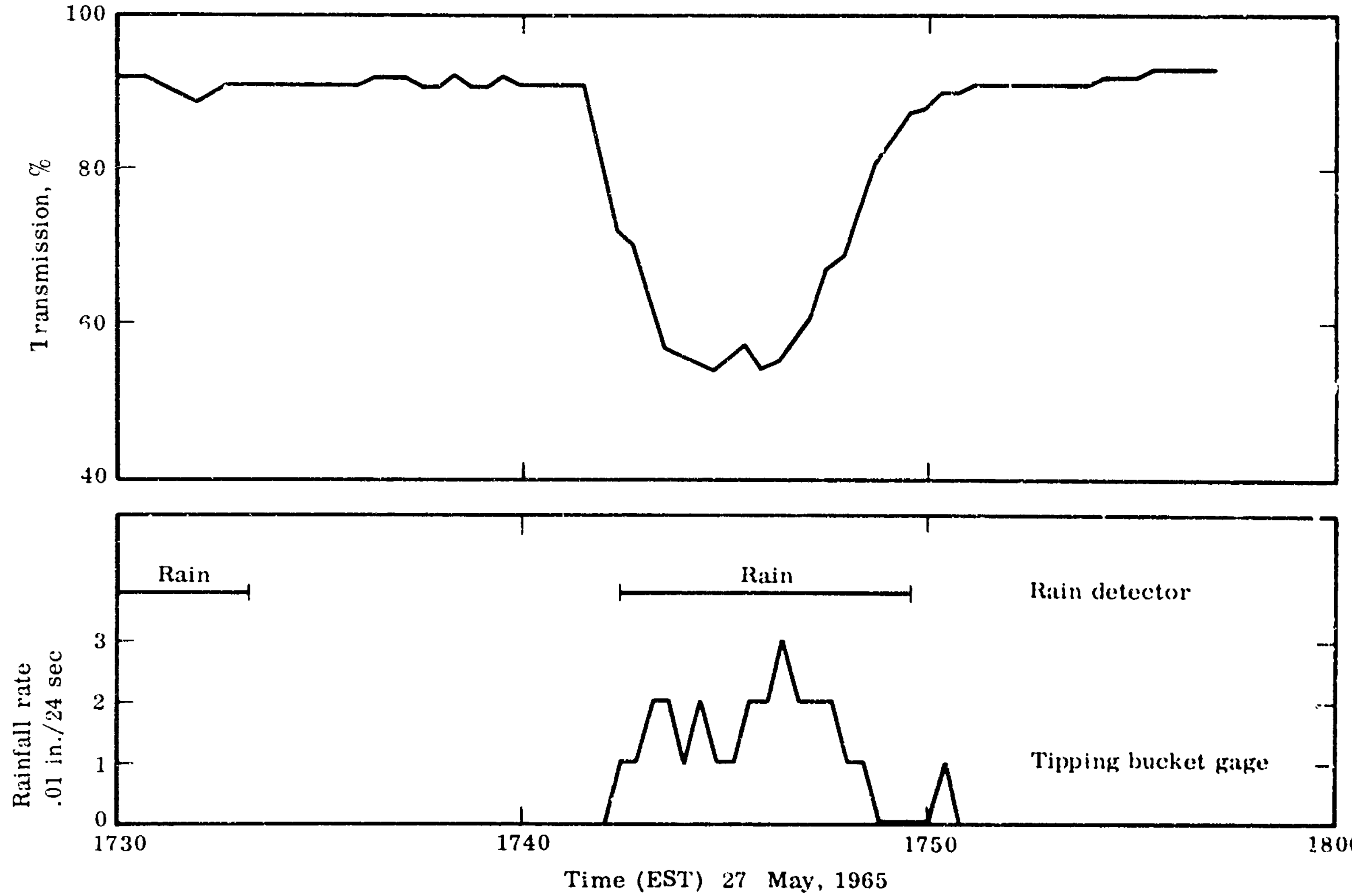

Fig. B-8. Simultaneous transmission and precipitation observations at 24-second intervals in showers at station 4 on 27 May, 1965.

VIII. COMPARATIVE STUDIES OF LOW CLOUD AND FOG AT SELECTED MESONETWORK STATIONS

A. Statistical Summaries

A complete log of low cloud and fog occurrences for selected classes of cloud base height and visual range was presented in Table B-I for station 1. It is useful and informative to compare these data with simultaneous observations at other nearby stations. Such a comparison for two classes of low-cloud heights is shown in Table B-III for Stations 1, 2, 3, 4, 5, and 10. In all cases, time periods for which data were missing in processed form from any one of these stations were omitted. A similar summary of two classes of low visual range is given in Table B-IV. However, in Table B-IV totals are not given for Station 4 since the transmissometer was inoperative in cases 13 to 16. All durations were obtained from 4-minute averages (transmission) or 4-minute modal values (cloud height).

It is immediately apparent from these tables that both the occurrence and duration of low cloud heights were markedly less uniform within the innermost circle of mesonetwork stations (Stations 1, 2, 3, 4, and 5) than the occurrence and duration of low visual ranges at the same stations. A second striking feature seen in Table B-IV was the large difference in total hours of low visual range between Station 10 (a few hundred feet from the ocean) and all other stations (a few miles inland). In some instances low cloud heights occurred apparently as a result of vertical obscuration in dense fog, and thus differences in duration may have been due to differences in the vertical depth of the fog from station to station. Consequently, a combination summary for visual range less than or equal to 1/2 mile and/or cloud-base height less than or equal to 200 ft is given in Table B-V. According to this summary only 4 of the 10 occurrences of low conditions occurred at all inland stations (disregarding 4-minute durations). Out of the 6 remaining occurrences 4 involved primarily low clouds rather than low visual ranges.

B. Analyses of the Onset and Ending of Low Cloud and Fog at NAFEC

According to Table B-I low cloud (cloud-base height ≤ 200 ft) and/or fog (visual range ≤ 1/2 mi) in excess of 4-minute duration occurred at Station 1 in 8 of the 16 data collection periods for which observations were available from all inner ring stations. With the exception of case 16, involving intermittent, apparently scattered low cloud, the onset and ending of each period of low conditions at Station 1 was studied with the aid of data from nearby stations.

Of the 3 periods for which observations were available during the initial appearance of low cloud or fog, two (cases 14 and 25) apparently resulted from the formation of shallow radiation fog under clear skies at night. There was no evidence of advection and the times of formation varied widely (4-5 hours) from one station to another within a 5 mi radius of Station 1. This is not surprising in view of previous studies in which large differences were found in the duration and times of formation of shallow ground fog along runway 13-31 at NAFEC [2]. In the third case (case 19) the leading edge of a dense fog bank, possibly warm frontal in nature, moved regularly from west to east across the network.

Observations during the ending of low cloud and fog were available for all 7 cases. The times of ending of low visual range (visual range ≤ 1/2 mile) are shown in Fig. B-9 for cases 7, 13, 17, 19, 22, and 25. The general trend of the times in Fig. B-9 suggests

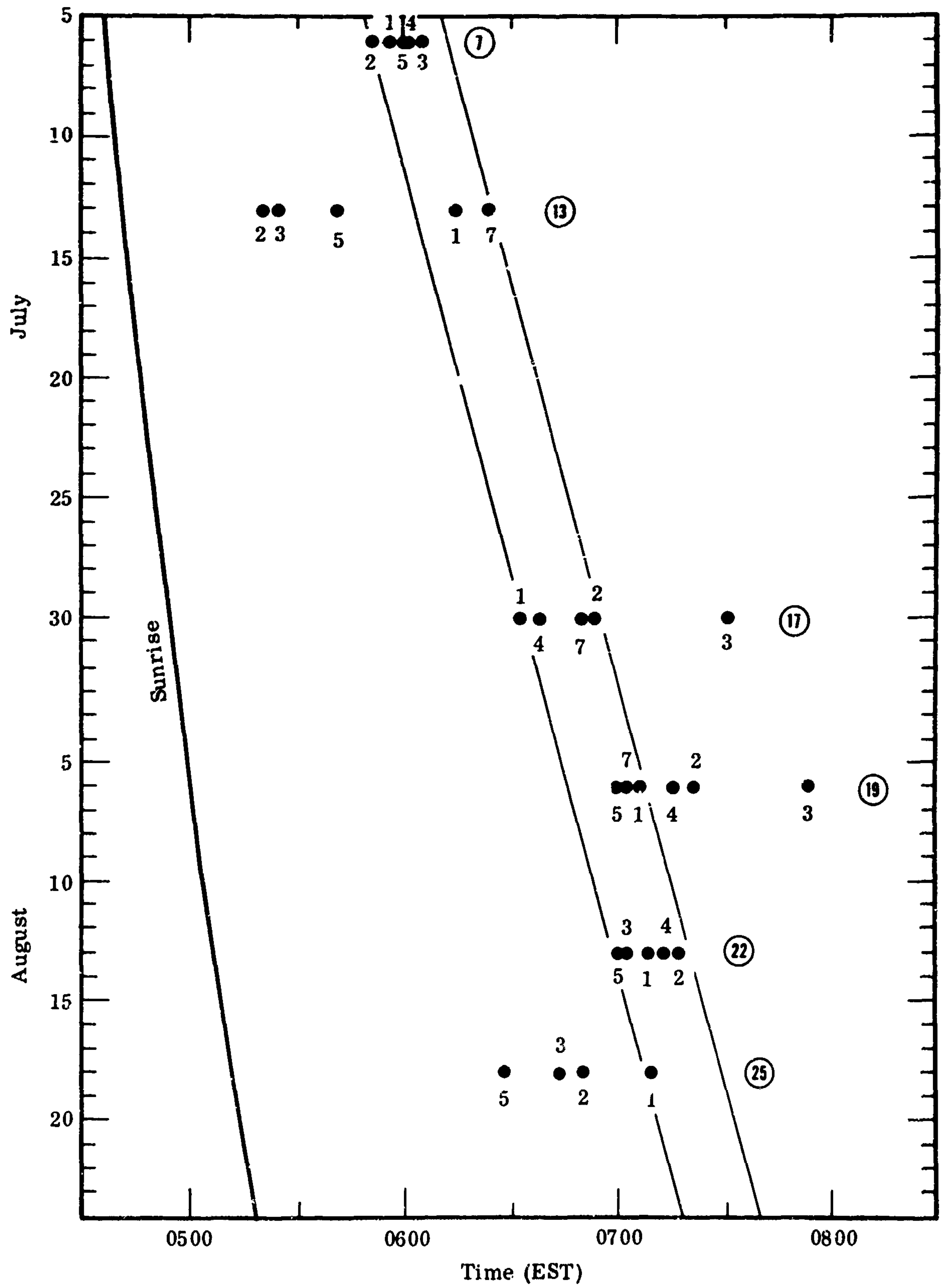

Fig. B-9. Times of fog endings at individual stations in relation to sunrise times in 6 cases. Case numbers in circles.

that solar heating was largely responsible for the dissipation or lifting of fog in these cases. Twenty of the thirty endings shown for individual stations occurred within a band of width 22 minutes as shown by the sloping straight lines. The trend of the clusters of points broadly agreed with the trend in sunrise times. There were slight indications also of increasing lag times as the season progressed.

In case 13 the presence of low cloud with a base of 500 to 600 ft. at stations 2, 3, and 5 but not at stations 1 and 7 during the ending of fog may have been responsible for the early endings at the former stations. At all stations shown and at Station 4 for which transmissometer data were not available the fog lifted to stratus with bases greater than or equal to 200 ft between 0615 and 0635 EST. The reasons for the apparent late endings (case 17, Station 3, and case 19, Stations 2, 3, 4) and for the early endings in case 25 are unknown. It is possible, however, that a more thorough analysis than was possible at this time would show that these discrepancies were due to mesoscale effects rather than to local microscale effects.

In the remaining case (case 14) the fog lifted to stratus between 0300 and 0400 EST apparently in response to an increase in wind speed (winds of 8 to 11 knots were reported at Atlantic City). The final period of fog in this case was of sufficient depth to be recorded by the rotating-beam ceilometer and showed evidence of movement from southwest to northeast in agreement with the surface wind direction.

C. Terrain Influences

The large differences between low cloud and fog observations at Station 10 and those at inland stations shown in Tables B-III, B-IV, and B-V were found to be due primarily to

(a) No fog at Station 10 (or at Station 8 when observations were available) under conditions favorable for radiation fog at inland stations; e.g., cases 7, 13, 14, 17, 22, and 25.

(b) Rapid dissipation of fog or low cloud while moving from ocean to land. On two occasions scattered remnants of the low cloud reached the nearest inland station (Station 5) in southerly flow.

Because of these effects, Station 10 was of little use in summer months as a predictor station for inland stations using simple techniques involving unmodified translation of low cloud base and visual range patterns. However, data from Station 10 in conjunction with data from the other mesonetwork stations should contribute significantly to an improved understanding of the processes of fog formation and dissipation.

TABLE B-III

TOTAL TIMES (min) WITH 4-MINUTE MODAL CLOUD-BASE HEIGHT (H) ≤ 500 ft (H ≤ 5) AND ≤ 200 ft (H ≤ 2) AT 6 MESONETWORK STATIONS (IN SAMPLING PERIODS FOR WHICH DATA WERE AVAILABLE FROM ALL STATIONS)

Case No.	Station No 3		2		1		4		5		10	
	H ≤ 5	H ≤ 2	H ≤ 5	H ≤ 2	H ≤ 5	H ≤ 2	H ≤ 5	H ≤ 2	H ≤ 5	H ≤ 2	H ≤ 5	H ≤ 2
2	288		212		164		556	12	264	16	392	188
3							4	4				
4			72	64			36	24			4	4
5	36		60		4		32	4	4		8	
7	12	12	48	48	4		36	36	40	40	20	16
13	60		140	12	32		104	4	112	16	164	8
14	68		100		120	36	164	8	172		224	216
15					4	4						
16					48	48					76	20
18			24		4	4	52				8	4
19	188	188	348	348	4	4	276	268			32	32
21							8				20	12
22	4	4	96	96			60	60				
24												
25							52	52			4	4
27												
Totals, Min	656	204	1100	568	384	96	1380	472	592	72	952	504

TABLE B-IV

TOTAL TIMES (min) WITH VISUAL RANGE (V) LESS 1 MI AND ≤ 1/2 MI AT 6 MESONETWORK STATIONS

Case no	Station no 3		2		1		4		5		10	
	V ≤ 1	V ≤ 1/2	V ≤ 1	V ≤ 1/2	V ≤ 1	V ≤ 1/2	V ≤ 1	V ≤ 1/2	V ≤ 1	V ≤ 1/2	V ≤ 1	V ≤ 1/2
2									24			
3												
4							4					
5									92	68		
7	42	36	32	24	36	28	44	32	44	32		
13							M	M				
14							M	M			156	72
15							M	M				
16							M	M				
18	152	24			4	0			4	0		
19	396	354	444	408	412	362	336	258	452	424	92	76
21	40	0										
22	100	92	112	108	100	92	104	88	96	92		
24												
25	240	188	240	232	152	144	20	4	216	204	8	0
27												
Totals, Min	976	724	828	772	704	626	-	-	904	920	2[illegible]	14[illegible]

M - Transmissometer Inoperative

TABLE B-V

TOTAL TIMES (min) WITH CLOUD-BASE HEIGHT H ≤ 200 FT AND/OR VISUAL RANGE V ≤ 1/2 MI AT 6 MESONETWORK STATIONS

Case No	Station no 3	2	1	4	5	10
2				12	16	188
3				4		
4		64		24		4
5				4	68	
7	44	48	28	44	44	16
13				M		8
14			36	M		228
15			4	M		
16			48	M		20
18	24		4			4
19	572	416	366	340	424	100
21						12
22	92	116	92	100	92	
24						
25	188	232	144	56	204	4
27						
Totals	920	876	722	-	848	584

M - Transmissometer inoperative